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CATECHISM

OF

CENTRAL STATION GAS ENGINEERING

IN THE UNITED STATES

UNIV. OF
CALIFORNIA

Compiled from the Questions and Answers sent out
to the Practical Class,
TRUSTEES GAS EDUCATIONAL FUND

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PREFACE

The matter in this volume has been compiled from the questions and answers sent out to the members of the Practical Class, which has been taught by correspondence since 1895, at first by the Committee on Education of the American Gas Light Association, and since 1899 by the Trustees Gas Educational Fund.

These questions and answers have been printed in the Proceedings of the American Gas Light Association and the American Gas Institute, but many requests have been made that they be published in one volume, arranged according to subjects, and this book has been prepared to meet this demand.

Among the questions there have been necessarily many covering the same subject from slightly different standpoints. In gathering them together it has been thought best, in some cases, to include more than one question and answer on a subject, even though this involved repetition.

Answers or portions of answers which are enclosed in quotation marks, without being credited to any authority, have been taken from the answers sent in by members of the Class. Those which are neither quoted nor credited, have been prepared during the regular course of the class work by the Trustees.

It is hoped that, although primarily intended to give the younger workers in the gas business a better knowledge of the principles involved, and the apparatus employed in this business and to aid them to do better work, these questions and answers will also be of service to the older workers in recalling to them the reasons for methods of operation which have come to be accepted as a matter of course.

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CATECHISM

OF

CENTRAL STATION GAS ENGINEERING

IN THE UNITED STATES

SECTION I—GENERAL DEFINITIONS.

1. Illuminating gas may, generally speaking, be divided into three classes, each class bearing the name of the material, or one of the materials, from which it is made. Give the name of each class, the materials from which each is made, and the useful products, other than gas, resulting from the process.

Ans. "Generally speaking, illuminating gas may be divided into the following three classes:—Coal gas comes first, with by-products of coke, tar and ammonia (gas liquor). It is made by the dry distillation of bituminous coal.

"Water gas, or more properly carburetted water gas, comes next, with tar as a by-product. It is made by decomposing steam by contact with incandescent coal or coke and enriching it with oil, or more properly speaking with oil gas.

"Then comes oil gas. This is made by the distillation of oil, and has tar as a by-product."

2. What is coal gas? What is water gas? What is carburetted water gas? What is oil gas? What is the average composition of each kind of gas?

Ans. Coal gas is the gas resulting from the dry distillation of coal. Water gas is the gas produced when steam is decomposed by contact and union with carbon at a high temperature. It is a non-luminous gas. Carburetted water gas is the gas produced by adding to and mixing with water gas a certain amount of oil gas, the mixture possessing an illuminating value dependent upon the proportions in which the water gas

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and oil gas are mixed. Oil gas is the gas resulting from the destructive distillation of oil (liquid hydrocarbons).

The average composition of each kind of gas is as follows, coal gas and carburetted water gas being taken after purification with iron sponge or mass :

	COAL GAS.	WATER GAS.	CARBURETTED WATER GAS
Carbon Dioxide, CO_2	1.60%	6.3%	2.7%
Oxygen, O_2	0.39%	0.5%	0.7%
Heavy Hydrocarbons	4.25%	——	12.8%
Carbon Monoxide, CO	8.04%	33.6%	30.7%
Hydrogen, H_2	47.04%	50.2%	32.4%
Marsh Gas, CH_4	36.02%	2.7%	13.9%
Higher Paraffins, C_nH_{2n+2}	——	——	2.4%
Benzene Vapor, C_6H_6	0.50%	——	0.6%
Nitrogen, N_2	2.16%	6.7%	3.8%
	100.00%	100.0%	100.0%

The composition of oil gas varies very much with the oil used and the temperature at which it is gasified. Two analyses are given below, No. 1 being that of gas made from Scotch shale oil distilled at a comparatively low temperature and No. 2 that of gas made at a high temperature.

	No. 1.	No. 2.
Hydrogen, H_2	16.85%	12.44%
Unsaturated Hydrocarbons	44.83%	35.65%
Saturated Hydrocarbons		
Ethane, C_2H_6	17.30%	45.37%
Marsh Gas, CH_4	19.00%	
Carbon Dioxide, CO_2	0.63%	0.74%
Oxygen, O_2	0.24%	2.00%
Nitrogen, N_2	1.15%	3.20%
Carbon Monoxide, CO	——	.60%
	100.00%	100.00%

3. Give the name of each part of the apparatus used in the manufacture and distribution of coal gas, beginning at the retort and ending at the consumer's burner.

Ans. "Retort, stand pipe, bridge pipe, dip pipe, hydraulic main, foul main, hot scrubber, exhauster, condenser, tower scrubber, rotary scrubber, centre seal, purifiers, station meter, holder, street main governor, street mains, service pipe, meter connections, consumer's meter, house pipe, fixture and burner."

4. Name the principal pieces of apparatus necessary in a coal gas works, and state briefly the function of each.

Ans. The principal pieces of apparatus necessary in a coal gas works are: retorts, stand, bridge and dip pipes, hydraulic main, tar extractor or hot scrubber, exhauster, condensers, washers or scrubbers, purifiers, station-meter and holders.

The retorts are the closed, heated vessels in which the coal is distilled; the stand, bridge and dip pipes carry the gas from the retorts to the hydraulic main, the liquor in which forms a self-acting seal preventing the return of the gas to the retorts; the tar extractor removes the heavy tar from the gas while it is still hot; the exhauster relieves the retorts from the pressure thrown by the weight of the holder and the resistance met with by the gas in passing through the various pieces of apparatus between retorts and holder; the condensers gradually cool the gas to the proper temperature (about 60° F.); the washers and scrubbers remove the ammonia and part of the sulphuretted hydrogen and carbon dioxide; the purifiers remove the remainder of the sulphuretted hydrogen, some of the other sulphur compounds, and, if lime is used, the carbon dioxide; the station-meter measures the gas as it is made, thus showing the results that are being obtained; and the holders enable the rate of production to be kept constant by storing the excess gas produced during the time of minimum demand to send it out during the time of maximum demand.

5. Name, in what you regard their proper order, the parts of a coal gas plant, from the hydraulic main to the purifiers, and give your reasons for so arranging them.

Ans. 1st. Hydraulic main. 2nd. Hot scrubber and tar extractor; because it is important that the gas pass through this apparatus at the temperature at which it leaves the hydraulic main, in order that the tar may be removed before it has cooled off, and, therefore, before it has gained any additional ability to absorb illuminants from the gas. 3rd. Exhauster; because it is important to have as few parts as possible of the apparatus under vacuum. As ordinarily run, all the apparatus between the hydraulic main and the exhauster contains gas at a partial vacuum, while the apparatus beyond the exhauster is under pressure. 4th. Condenser; because it is important to cool the gas before it comes in contact with the water which is to absorb the ammonia. The cooler the water and gas the more ammonia will the water absorb per gallon. 5th. Washer and scrubber; because better purification results are obtained in the purifying boxes, and a greater yield of ammonia in marketable form, that is, in liquor, if the washer and scrubber precede the purifiers. 6th. Purifiers; because when the gas has been through the apparatus referred to above it is in condition to enter the boxes and give up its sulphur impurities and carbonic acid to the purifying material, if this is lime; or to give up its sulphur impurities only, if the purifying material is oxide of iron.

6. Give the name of each part of the apparatus used in the manufacture and distribution of water gas, beginning at the generator and ending at the consumer's burner.

Ans. "Generating apparatus, wash box, scrubber, condenser, relief holder, exhauster, centre seal, purifiers, station meter, storage holder, street main governor, street mains, service pipe, meter connections, consumer's meter, house pipe, fixture and burner."

7. Name the principal pieces of apparatus necessary in a carburetted water gas works, and state briefly the function of each.

Ans. The principal pieces of apparatus necessary in a carburetted water gas works are: the generator, carburetter, superheater, wash-box, scrubbers, condensers, relief holder, exhauster, purifiers, station-meter and storage holder.

The generator is the vessel in which water gas (blue gas) is produced by the action of incandescent carbon upon steam;

the carburetter is the vessel in which the oil is vaporized in the presence of the water gas produced in the generator; the superheater is the vessel in which is completed the gasification of the oil begun in the carburetter, with the formation of a fixed oil gas which is mixed with the water gas; the wash-box answers the same purpose as the hydraulic main in a coal gas plant, forming an automatic seal preventing the return of gas to the generating apparatus; the scrubber is a tar extractor and also acts in connection with the condensers in cooling the gas; the relief holder compensates for the intermittent action of the generating apparatus and permits a steady flow of gas through the pieces of apparatus following it; the exhauster draws the gas from the relief holder and forces it through the purifiers and station-meter into the storage holder, the functions of these pieces of apparatus being the same as those of the same parts of a coal gas plant.

8. What is the action of the water seal as applied in the hydraulic main of a coal gas works and the washbox of a water gas works?

Ans. The purpose of the water seal as applied in the hydraulic main of a coal gas works and the washbox of a water gas works, is to permit the free passage of the gas from the generating apparatus and to prevent its return. This "check valve" action is due to the large difference between the area of water in the washbox and that in the dip pipe. If the dip pipe has an internal diameter of one foot and that of the washbox is five feet, the area of the water in the washbox is approximately twenty-five times the area of the water in the dip pipe.

If the dip pipe dips two inches in the water in the washbox, a pressure only a trifle over two inches higher than the pressure in the washbox is all that is necessary to force gas through it into the washbox. But before any gas can pass back from the washbox into the dip pipe, all the water in the washbox above the bottom edge of the dip pipe must be forced up into the pipe. As the area of the washbox is twenty-five times the area of the dip pipe, the water in the box will fill the dip pipe 25 × 2 = 50 inches high before gas can pass. The above figures approximate those obtaining in actual practice. The coal gas hydraulic main operates on the same principle.

9. Name the useful by-products or residuals produced in addition to the gas in the manufacture of coal gas. In the manufacture of carburetted water gas.

Ans. The useful by-products or residuals produced in the manufacture of coal gas are: Coke, retort carbon, tar, ammoniacal liquor, spent oxide and spent lime.

When naphtha is used in the manufacture of carburetted water gas the only residual is a small quantity of thin tar, which is of no value except to be burned under the boilers. When crude oil or gas oil is used, however, a good tar, which in many places commands a ready sale, is formed in larger quantities.

10. What is a struck bushel? What is a heaped bushel? What is an American gallon? What is an Imperial (English) gallon? Give your answers in cubic inches and cubic feet.

Ans. The American "struck" bushel is the capacity of a cylindrical vessel having inside measurements of 18½ in. diameter and 8 in. high = 2,150.42 cubic inches = 1.2444 cubic feet. A "heaped" bushel is such a cylinder surmounted by a cone not more than 6 in. high, and having as a base the diameter of the outside of the containing vessel, this vessel being 19½ in. in outside diameter. It will be seen that the diameter of the cone which forms the "heap" is 1 in. greater than the diameter of the interior of the vessel. This is because the "heap" is supposed to extend to the outside of the vessel used for measuring a bushel. The "heaped" bushel is, therefore, 2,747.7 cubic inches = 1.5901 cubic feet. This is the capacity of a cylinder 18½ in. diameter and 8 in. high, with a cone 19½ in. diameter and 6 in. high. The American Gas Light Association has adopted this bushel, using the "heaped" measure for coke and the "struck" for lime. The "struck" bushel is also used for measuring iron oxide.

An American gallon contains 231 cubic inches, and equals in volume 8.33888 pounds of water at 39.1° F., or maximum density, and 30 in. barometric pressure. It equals 0.1336 cubic feet.

An Imperial (English) gallon contains 277.274 cubic inches and equals in volume 10 pounds of water at a temperature of 62° F. and 30 in. barometric pressure. It equals 0.1604 cubic feet. It therefore equals 1.2 American gallons, and this fact should be borne in mind when reading articles published in the English Gas Journals.

SECTION II—MANUFACTURING MATERIALS.

PART I—BITUMINOUS COAL.

11. What are the properties that must be possessed by a coal to fit it for being used for the manufacture of coal gas?

Ans. The most valuable coals for use in the manufacture of coal gas are those which contain a small percentage of ash and sulphur, a comparatively large percentage of volatile matter of good illuminating value, and which possess coking qualities that permit the production of good salable coke amounting to from 55 per cent. to 65 per cent. of the original weight of the coal.

A good Pittsburg coal, which may be taken as the standard gas coal of the United States, will show the following analysis by weight:

Volatile Matter	33% to 35%
Fixed Carbon	60% to 55%
Ash	6% to 4%
Sulphur	0.4% to 0.6%

Under proper conditions an increase in any direction may compensate for a proportionate decrease in others. Thus, in cannel coals a large yield of rich gas balances a small production of poor coke, while in some bituminous coals an extra amount of sulphur is offset by an increased yield of gas or a harder, better coke. Comparative cheapness of price may also turn the scale in favor of an otherwise inferior local coal. But, under ordinary conditions, a coal fulfilling the requirements given above is the best for general use in coal gas manufacture.

12. Name the principal gas coal fields of the United States and Canada, and give the general characteristics of the coal from each field.

Ans. The principal gas coal fields of the United States are located in the Appalachian coal field which stretches along the Appalachian mountain range from New York to Alabama, but gas coal is also found in each of the other great coal fields, viz.: the Middle in Illinois, Indiana and western Kentucky, the Western in Missouri, Iowa, Nebraska, Kansas, Arkansas and Oklahoma and the fields in the far West, the limits of which have not yet been clearly defined nor their resources fully developed.

Among the gas coal districts of the Appalachian field the Pittsburg district which lies immediately east and south of Pittsburg on the Allegheny, Monongahela and Youghiogheny Rivers is prominent. The coal from this district is comparatively hard and dense so that it can be transported without excessive breakage, and yields a good amount of gas of good quality and a clean hard coke. The percentage of sulphur contained in it is small, being usually well under 1%. A fair gas coal is also found in Jefferson and Beaver counties, Pennsylvania, but this coal is not quite as good as that from the main body of the Pittsburg field.

Another important district is the West Virginia district located in the northern part of West Virginia along the banks of the Monongahela River. The coal in this district is very similar to that obtained from the Pittsburg district, but is less able to stand handling without disintegrating and is apt to contain more sulphur, although some samples show very well in this respect.

The Kanawha district, also in West Virginia, extends back for about 30 miles on each side of that portion of the Kanawha River between Kanawha Falls and Charleston. The coal produced here differs only slightly from the coals mentioned above, except in being apt to contain more sulphur than is found even in the coal mined in the West Virginia district, the percentage running up as high as 1½% in some samples, although as low as 0.6% in others. Cannel coal is also found in paying quantities in this district.

Kentucky possesses a little gas coal, but hardly enough to be taken into consideration if it were not for its large deposits of rich cannel coals. The best known of these is the Breckenridge, which besides giving off a large amount of rich volatile matter yields also a fairly good coke which can be mixed to a proportion of 10% with the coke from ordinary gas coal without depreciating the latter.

In Tennessee good gas coal is found in Scott and Anderson counties, while in Campbell county an excellent cannel coal is mined which is similar to the Breckenridge and is known as Jellico cannel. The gas coal is a clean hard coal fully equal in all respects to that obtained from the Pittsburg district.

In Alabama there are three coal fields, the Cahaba, the Coosa and the Warrior, in each of which some coal is found which can be used as gas coal, but the best coal for this purpose comes from the Corona seam in Walker county. This coal is clean and hard enough to bear handling well.

Although Ohio, Indiana and Illinois produce coal that is used locally for gas making, they cannot be considered as gas coal districts, since the coal is only used for this purpose when the gas works are practically over the mines, and Pennsylvania coal is in demand throughout these States for use in preference to the local coal.

In Kansas the Cherokee field produces a gas coal that is good in every respect except that of the amount of sulphur contained in it, and this runs from 2½% to 5% and even as high as 8% in some samples.

The Choctaw country in Oklahoma yields a coal which is clean and hard, stands handling and produces a good coke. It closely resembles the Pennsylvania coals although it contains more sulphur and ash than the latter, the percentage of sulphur being a little over 1%.

The Trinidad field in Colorado also furnishes a clean bright coal that is low in sulphur and is said to give a good yield of good quality gas and from 60% to 70% of compact coke.

On the Pacific coast the South Prairie and Roslyn mines in Washington give a coal from which a fair amount of fairly good quality gas can be obtained and which is low in sulphur, but produces a soft, friable and comparatively poor coke.

The principal gas coal fields in Canada lie on Glace Bay and Cow Bay in Cape Breton. These provincial coals were formerly used quite extensively by gas works situated on the Atlantic coast of the United States. They yield a good amount of gas of a quality better than average, but they disintegrate easily, contain a fairly large amount of sulphur and are very susceptible to spontaneous combustion. At the present time their use has been practically abandoned in the gas works of the United States.

Average analyses of some of the coals mentioned above follow:

	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Pittsburg,	35 to 40%	54 to 58%	3 to 5%	0.6%
West Virginia,	35 to 40%	53 to 57%	4 to 7%	1.0%
Kanawha,	34 to 40%	55 to 62%	2 to 4%	0.6 to 1.5%
Breckenridge Cannel,	47%	42%	10%	0.6%
Tennessee Gas Coal,	36 to 39%	56 to 60%	1.8 to 3%	0.8%
Jellico Cannel,	50%	35%	14%	0.7%
Alabama—Corona Seam,	34 to 41%	50 to 59%	7 to 9%	0.7%
Kansas—Cherokee,	37%	52%	9%	2.5 to 8%
Oklahoma,	37 to 40%	51 to 55%	4 to 7%	0.9 to 1.3%
Washington—Roslyn,	28%	61%	9%	0.1%
Colorado—Trinidad,	33 to 37%	51 to 57%	9%	0.7 to 1.4%
Cape Breton,	35%	53%	5.5%	3%

13. Give the meaning of the terms "run of mine," "¾-inch" and "1½-inch" as applied to bituminous coal, and state, with your reasons for the statement, which class of coal gives the best carbonizing results.

Ans. "Run of mine" coal is coal which is shipped from the mine in the condition in which it is mined and loaded into the mine cars, being run from these cars directly into the railroad cars, or the boats, as the case may be, without being screened. It consists therefore of a mixture of lumps of all sizes with slack or dust.

"¾-inch" coal is coal that has been passed over a ¾-inch screen before being loaded into the railroad car, or the boat, and has therefore been freed from the slack and dust as well as from the smaller pieces of coal that pass through the screen.

"1½-inch" coal is coal that has been passed over a 1½-inch screen, and is therefore still more free from small pieces than is ¾-inch coal.

The screens used at the tipples of the coal mines are, as a rule, not made with meshes, but are formed by parallel bars of iron running the long way of the screen. In a ¾-inch screen the bars have a clear space ¾-inch wide between them, and in a 1½-inch screen the clear space is 1½ inches wide. The openings in the screens are long narrow slits, through which will pass not only the small cubes but also long pieces of small cross-section.

The screened coal gives better carbonizing results than the "run of mine," since the latter is not only harder to burn off, owing to the dust contained in it, which forms in the retort a compact mass through which the heat can only penetrate slowly and with difficulty, but also contains more dirt and slate and a larger percentage of sulphur and will not yield as much gas per pound, or as clean gas, even when carefully and thoroughly carbonized. The majority of companies manufacturing coal gas buy ¾-inch coal, it being thought that as long as the slack is screened out there is no practical difference in value between the small lumps and the larger ones. However, at least one large company uses 1½-inch coal, and the engineer of this company considers that the results obtained from it are enough better than those obtained from ¾-inch coal to more than compensate for the higher price charged for it.

14. What, if any, are the reasons for preferring lump coal to slack, or "run of the mine," for use in coal gas retorts?

Ans. Lump coal, when exposed to heat in a retort, yields its gas more readily than does slack coal or "run of the mine," "run of the mine" being a mixture of slack and lump. It loses gas less rapidly when stored. Lump coal also contains ordinarily a smaller percentage of ash than does slack, is more readily dried, and absorbs moisture more slowly. The net result is that lump coal stores better, and yields more gas and better coke, with a smaller consumption of fuel under the retorts, than does slack, or "run of the mine."

15. Is there any reason why gas coal that has been put into the coal shed of a gas works should not be left there indefinitely, if the supply is maintained so that it is not necessary to use it?

Ans. For any given gas works the answer to this question depends upon the character and qualities of the coal used.

Some gas coals break up very badly when stored, the lumps becoming gradually converted into slack, and as this breaking up exposes fresh surfaces, as well as a greater surface in proportion to the volume, to the action of the air, and thus makes it easier for slow oxidation of the coal to take place, a comparatively rapid deterioration sets in and may continue until the value of the coal is practically destroyed. Under these conditions it is not advisable to keep coal in stock for any length of time and a practice should be made of working out the oldest stock at regular and short intervals.

However, many of the gas coals used in this country, particularly those from Western Pennsylvania, do not depreciate to any great extent when stored, except on the surface of the pile, and even in this portion the loss is very small after the end of the first six months, so that such coal when stored in fairly deep piles, protected from the weather, will suffer only a small total depreciation, the larger part of which takes place in the first year, even when stored for many years. When using coal of this kind, any stock that it is not necessary to use can be left in store indefinitely as far as loss in gas making value is concerned, since after having been stored for a year, the future depreciation on it will be much less than would be suffered by fresh coal stored in its place, and it is better to use the fresh coal, even if it is not possible to also make a saving in cost of handling by working the fresh coal directly into the retort house instead of having to put it into and take it out of the shed.

But even when the coal does not depreciate sufficiently to call for working out old stock, it is advisable to do this every few years and clean out the shed, for the purpose of checking the accuracy of the coal account as carried on the books, since in most coal sheds it is impossible to secure an accurate check in any other way. If, however, the coal is stored in pockets, into one of which a known quantity has been put and allowed to remain undisturbed, or if the stock pile is kept entirely separate from the rest of the coal and not drawn upon, there will be no reason for not keeping indefinitely a stock of coal of the character spoken of in the preceding paragraph, except an emergency when no other coal can be obtained.

16. What is thought to be the cause of spontaneous combustion in bituminous coal? Is this combustion more apt to occur in dry coal or in wet coal, in small coal or in large coal?

Ans. Investigations into the causes of the spontaneous ignition and combustion of bituminous coal have been made chiefly with reference to the occurrence of such combustion on board of coal laden vessels, but there is no reason why the conclusions reached in the case of coal stored on board vessels should not apply to coal stored in sheds. The theory that is now generally accepted as a result of the careful investigations of several Commissions is that the occurrence of any spontaneous increase in the temperature of coal is due chiefly to the condensation and absorption by the coal of oxygen from the air, which causes heating and thus promotes the chemical combination of the oxygen with the volatile hydrocarbons in the coal and even with some of the carbon itself. The conditions favoring the occurrence of this action to an extent sufficient to generate enough heat to effect the ignition of the coal are "a moderately high external temperature; a broken condition of the coal, affording fresh surfaces for absorbing oxygen; a supply of air sufficient for the purpose, but not in the nature of a strong current adequate to remove the heat; a considerable percentage of volatile combustible matter or an extremely divided condition." The action of moisture upon the sulphur present in the form of iron pyrites is a secondary cause of heating principally because of its effect in breaking up the coal and presenting fresh surfaces for the absorption of oxygen.

Since the smaller the pieces the greater the proportion between the surface exposed to air and the mass of coal, small coal affords much greater opportunity for the occurrence of the reaction between oxygen and coal which causes spontaneous combustion, and therefore such combustion is more apt to occur with small coal than with large coal. In coals that contain much iron pyrites the presence of moisture increases the liability to spontaneous combustion because, as has been previously stated, the moisture and pyrites act together to break up the coal and thus expose a larger extent of fresh surface to the action of oxygen. When iron pyrites is absent, or present to only a small extent, the presence of moisture retards the absorption of oxygen and therefore reduces the danger of spontaneous combustion, and in fact this danger can be entirely done away with by keeping the coal thoroughly soaked with water.

17. What danger is to be guarded against in storing bituminous coal? Is this danger greater with dry coal or with wet coal? With fine coal or with large coal? What precautions should be taken to guard against it?

Ans. Spontaneous combustion is a danger that should be guarded against in storing bituminous coal. This danger is greater with wet coal than with dry, with fine than with large coal. To guard against it care should be taken in storing bituminous coal in a coal shed that no excessive breakage occurs during the handling of the coal into the shed; that it is dry and large when received and is handled only in dry weather; that it is well protected from the weather when in the shed, and that it is not exposed to external heating as would be the case if it were stored in close proximity to a boiler or bench of retorts or over steam pipes. The floor of the shed should be dry, and made of incombustible materials, and all roof or track supports passing through and imbedded in the coal should be made of iron or brick. If the storage of wet or fine coal cannot be avoided, no large amount of such coal should be piled together in any one place, but it should be, as far as possible, distributed in a thin layer over the faces and top of the pile and allowed to become thoroughly dry before being covered with any other coal. It is best not to attempt any ventilation of the pile, since insufficient ventilation is much more dangerous than none at all, and from the nature of the case it is practically impossible to obtain sufficient ventilation. It is also well not to store coal recently mined, at least a month being allowed to elapse after mining before the coal is stored.

The taking of these precautions will tend to prevent the occurrence of any spontaneous increase in the temperature of the coal, since this increase is probably due chiefly to the condensation and absorption by the coal of oxygen from the air, which causes heating and thus promotes the chemical combination of the oxygen with the volatile hydrocarbons in the coal, and even with some of the carbon itself. The conditions favoring the occurrence of this action to an extent sufficient to generate enough heat to effect the ignition of the coal are "a moderately high external temperature; a broken condition of the coal, affording fresh surfaces for absorbing oxygen; a supply of air sufficient for the purpose, but not in the nature of a strong current adequate to remove the heat; a considerable percentage of volatile combustible matter or an extremely divided condition." The action of moisture upon the sulphur present in the form of iron pyrites is a secondary cause of heating principally because of its effect in breaking up the coal and presenting fresh surfaces for the absorption of oxygen.

To detect the existence of any heating before it has reached a dangerous point, 1 in. pipes should be either set up on the floor of the shed so as to be imbedded in the coal as the shed is filled, or else should be driven through the coal after the shed is filled. These pipes should be closed at the bottom, should reach from the floor of the shed to a point just above the top of the coal and should be spaced not more than ten feet apart, from centre to centre, throughout the whole space filled with coal. In each pipe should be placed a wire stretched by the weight of a small iron rod suspended from it and just long enough to allow the point of the rod to touch the bottom of the pipe. By keeping one hand closed around the wire and slowly drawing it up until the rod is reached, the existence of any abnormal temperature can be detected and the place where it occurs located. The exact temperature existing at any hot point can be determined by lowering thermometers down the pipes in which the wires are found to be heated. Under normal conditions, where there is no reason to anticipate trouble, the inspection of the condition of the wires need not be made oftener than once a week, but when any heating has been found, no matter how slight it is, or there is reason to believe that it may occur, observations should be made at least once a day. If the temperature becomes high at any point and continues to rise, steps should be taken at once to prevent any ignition of the coal. The safest method is to work into the pile at the hot point and expose the coal that is heating to the air by spreading it out in a thin layer. As long as the coal has not begun to burn this will stop the heating. If the coal has fired, the fire must be uncovered and then extinguished. It is of very little use to try to put out the fire without digging down to the coal that is burning.

PART 2—ANTHRACITE COAL.

18. What conditions, other than the size, would determine your choice in selecting one of several kinds of anthracite coal offered for use as the generator fuel in a carburetted water gas apparatus?

Ans. The object sought in selecting an anthracite coal for use as the generator fuel in a carburetted water gas apparatus is to obtain the coal that will produce the most gas at the smallest cost. The price being equal, the cost of the gas is affected by the quantity of gas that can be made from a given weight of fuel, the amount of sulphur compounds in the gas, the rate at which the gas can be made and the amount of labor required to handle the apparatus. The quantity of gas that can be made depends largely upon the amount of fixed carbon in the coal and also upon the hardness and ability to withstand handling, and the weight of the fuel above it in the generator, without breaking up into small pieces. The amount of sulphur compounds in the gas depends, of course, upon the amount of sulphur in the coal, other things being equal. The rate at which gas can be made is influenced by the ability of the coal to resist crushing, without which the fire cannot be kept in good condition for gas making, as well as by the amount and character of the ash through its influence upon the nature and quantity of the clinker formed. This latter also determines the amount of labor required for cleaning the fire, while the cost of labor for gas making proper depends upon the rate at which the gas is made.

The best coal for the purpose named is therefore the one that contains the largest percentage of fixed carbon and is hard enough not to break up into small pieces in the generator, or while being handled before being put into the generator, and shows only small percentages of sulphur and of an ash that produces a clinker that does not unduly obstruct the passage of the blast and steam through the fire, nor make the cleaning of the fire difficult. To fulfill this condition the ash should not contain much sulphur or iron. Since a red color is due to the presence of iron, the white ash coals give the least trouble from clinker.

It is, however, difficult to secure a coal that possesses all of the above qualities in the highest degree, and also entirely possible to pay too much for them. Therefore, in making a choice between different kinds of coal it is always necessary to balance advantages in one direction against disadvantages in another and so determine carefully the relative values of the different samples, selecting the one that is shown in this way to be the cheapest at its price.

19. What are the respective advantages and disadvantages of anthracite coal, gas coke, and furnace coke when considered with reference to their use as the fuel in the generator of a carburetted water gas apparatus?

Ans. Anthracite coal will contain less ash than gas coke and will therefore make less clinker than such coke. Since it is much denser than coke a given generator volume will hold a greater weight of fuel when coal is used and this fuel will neither heat up nor lose its heat as rapidly as coke. This permits of longer "runs" and "blows" and so reduces the percentage borne by the time required for opening and closing the valves in putting on and taking off the runs, to the total time during which the machine is in operation. With coal there is also the further advantage that the generator does not have to be opened as often for charging as is necessary with coke.

On the other hand the surface presented to the action of the blast and steam is smaller with anthracite coal than it is with gas coke, owing to the porous nature of the latter. The irregular form and roughness of the individual pieces of coke keep the fuel bed in a condition favorable for the general and intimate contact of both blast and steam with the carbon of the fuel. The heat can therefore be gotten up quickly and gas made at a rapid rate during the shorter run, and with quick workmen the increase of time required for handling the valves owing to the shortness of the blows and runs is not of great importance. It is, however, necessary when using gas coke to be very careful not to unduly prolong either the blows or the runs, since, owing to the rapidity with which coke is consumed, any over blowing increases the fuel account very greatly, while any extra length of run increases the amount of carbon dioxide in the gas very rapidly, because the fire cools off quickly.

In general it is probably true that fair results as to the quantity of fuel used per 1,000 cubic feet of gas and the quality of the gas made can be secured more easily with coal than with gas coke, but that, given good management and the necessary supervision to ensure the proper handling of each kind of fuel, there is little, if any, choice between the two materials.

Furnace or oven coke, unless it is made from carefully washed coal, or from coal that is originally free from ash, such as that used in making Connellsville coke, is apt to contain more ash than gas coke and to give trouble from clinker. It does not possess the density of anthracite coal nor is it as porous as gas coke. The 48-hour or soft coke makes a better generator fuel than does the 72-hour or hard coke. Opinions differ as to the relative merits of furnace coke and gas coke, some engineers preferring gas coke and others furnace coke under similar conditions.

Given the proper handling of each, there is, however, little difference between the three classes of fuel, and even slight differences in prices or in local conditions will be sufficient to turn the scale in favor of one or the other.

20. What size of anthracite coal and what size of coke is best suited for use as the fuel in the generator of a carburetted water gas apparatus? Give the reasons for your answer.

Ans. The sizes of anthracite coal that are usually considered available for use as the fuel in the generator of a carburetted water gas apparatus are:

Steamboat, consisting of pieces which pass through a screen in which the bars are set from 4 in. to 7 in. apart, the smaller sizes of coal having previously been screened out ;

Broken, consisting of pieces which fall through a screen with a 4 in. mesh, but pass over one with a 2½ to 2¾ in. mesh, and

Egg, consisting of the pieces which fall through a screen of 2¼ in. to 2¾ in. mesh, but pass over one with a 1½ in. to 1 ⅞ in. mesh.

Of these sizes, that known as broken has been found to give the best results for general use, though in very large generators, those over eight feet in diameter, the steamboat size might be better.

The advantages possessed by broken coal are, that the lumps are sufficiently large to maintain the bulk of the fire in an open state, which affords a ready passage to the air in blasting and the steam when making gas, and yet are small enough to present a large surface of carbon to be acted upon by the oxygen, and it is thus possible to secure the proper combination of the greater portion of both oxygen and carbon in each case. Smaller coal affords a larger total surface, but at the same time forms a large compact mass in the centre of the generator, through which the air and steam cannot pass readily. They therefore pass only through that portion of the area of the generator which lies between the outside wall and this compact mass in the centre. The larger size affords a freer fire, but much less total surface, and has moreover the disadvantage of being harder to handle.

In a paper on the "Selection of Anthracites for Water Gas," read before the American Gas Light Association, October 20th, 1892, Mr. C. R. Collins states that the inactive portion of the fire, which is due to the compacting of the coal in the centre of the generator, where the lumps can fit into each other more perfectly than they can in the space next the walls, "varies with the diameter (of the generator) and with the size of the coal ; thus in a particular generator egg coal renders about 30 per cent. of the fire partially inactive, the bulk of the work being done in the outer parts representing 70 per cent. of the fuel ; in the same way broken coal affects about 15 per cent. of the fuel bed, while steamboat coal leaves a practically free fire.'' He also states that steamboat coal presents approximately seven square feet of surface for each cubic foot of generator space ; broken coal ten square feet of surface per cubic foot of space, and egg coal twenty-two square feet of surface per cubic foot of space. These figures are for selected coal of the standard size in each case. In practice the steamboat coal will have some broken coal in it, the broken some egg and so on, and the presence of this smaller coal will increase the size of the inactive portion of the fire as well as the amount of surface presented to the air and steam. It is therefore important that, no matter what size is being used, the smaller pieces and slack should be screened out and not used in the generator, the coal used being kept as near the selected standard size as possible.

The members of the class should read Mr. Collins' paper, which can be found in the Proceedings of the American Gas Light Association, volume 10, page 82 ; in the American Gas Light Journal, volume 57, page 690, and in Progressive Age, volume 10, page 399.

What has been said above as to anthracite coal applies also to coke. When oven coke is used, the large pieces in which it comes from the ovens should be broken up to a size corresponding to broken coal before the coke is charged into the generator. On the other hand, the coke after being broken should be picked up with a fork in such a way as to leave behind the small pieces and dust which should not be used in the generator.

When coke made in coal gas retorts is used it does not require any breaking, but must be picked up with a fork to avoid the presence of small pieces and dust. It must be remembered that a fork can easily be used in such a way as to pick up almost as much fine stuff as a shovel, and that when loading coke which is to be taken to the generator the fork should be well shaken, while the coke is on it, for the purpose of dislodging the dust and small pieces that are held between the larger pieces as they are picked up.

PART 3—GAS OILS.

21. Name and describe the three grades of oil which are commonly used as the carburetting material in the manufacture of carburetted water gas.

Ans. The three grades of oil which are commonly used for carburetting water gas are crude oil, naphtha and gas oil, the last two being obtained from the first by fractional distillation.

Crude oil is petroleum just as it comes from the oil wells. It is a mixture of liquid hydro-carbons possessing different chemical compositions, specific gravities and boiling points (together with small quantities of other substances) and can be separated into these different substances by fractional distillation. It is found in nearly every country in the world but the most important fields are in the United States, Russia and Peru. The specific gravity of the petroleum obtained in Pennsylvania and Ohio varies from 0.80 to 0.85 (or 45° to 35° Baumé) water being 1.00. The color also varies, but is generally dark claret by transmitted light, and greenish by reflected light. The specific gravity of the crude oil found at Beaumont, Texas, is 0.91 to 0.92, or 24° to 22° Baumé. It is dark brown in color.

Naphtha is a general name given to that portion of the products of the fractional distillation of petroleum which comes off after gasoline has been driven off and before the fraction suitable for use as burning or lamp oils begins to come off. It is very volatile at ordinary temperatures and highly inflammable. It is practically colorless, though some samples show a decidedly greenish tinge by reflected light. Its specific gravity varies from 0.68 to 0.74, or 76° to 60° Baumé.

Gas oil is a general name given to that portion of the products of the fractional distillation of petroleum which comes off after the lamp oils and before the lubricating oils. It is too heavy and of too high a boiling point to use for lamp oil, but not viscous enough to make a good lubricant, and is chiefly valuable for the production of gas. Its color varies from quite light to very dark. Its specific gravity also varies, but will average about 0.84, or 37° Baumé.

22. How does the crude petroleum found at Beaumont, Texas, differ in its physical and chemical characteristics from the crude petroleum found in Pennsylvania?

Ans. The crude petroleum found at Beaumont, Texas, differs from Pennsylvania crude petroleum in specific gravity, color, flashing point and viscosity, and also in its ultimate chemical composition, especially as to the amount of sulphur it contains, the percentage of the total volume distilled between various temperature limits when the oil is subjected to fractional distillation, and the nature of the hydrocarbons of which it is composed.

The specific gravity of Beaumont crude petroleum is from 0.910 to 0.920, that of Pennsylvania petroleum from about 0.78 to 0.88, the average being about 0.83. The color of the former is a dark brown, that of the latter is usually either green or amber, although some samples are brown. The flashing point of Beaumont oil is higher than that of Pennsylvania oil. The former is less fluid than the latter.

According to the following table showing the ultimate chemical composition of samples of both Beaumont and Pennsylvania petroleum, the former contains less carbon and hydrogen, but considerably more sulphur than the latter.

	Beaumont	Pennsylvania
Carbon	85.03%	86.10%
Hydrogen	12.30%	13.90%
Sulphur	1.75%	0.06%
Oxygen and Nitrogen	0.92%	

The percentage of sulphur given for the Pennsylvania oil is rather smaller than usual, but this oil never contains more than 0.5% of sulphur. In the case of the Beaumont oil it is what may be called fixed sulphur, and in addition the oil, when fresh, contains, in solution, sulphuretted hydrogen, which is largely lost on standing, and can be almost completely eliminated by blowing air through the oil. If this sulphuretted hydrogen is included, the sulphur amounts to slightly more than 2%.

The volumes of the fractions distilled off at various temperatures and the temperature at which distillation begins in the two kinds of oil are:

	Beaumont	Pennsylvania
Distillation begins	230° F.	176° F.
Below 302° F.	2.5%	21.0%
Between 302° and 575° F....	40.0%	41.0%
" 575° " 662° F....	20.0%	14.0%
" 662° " 752° F....	25.0%	23.0%

Very little Beaumont oil distills over at temperatures below 300° F. and it produces no naphtha, but after this temperature is reached the percentages passing over between the same temperature limits up to 752° F. (400° C.) do not differ very materially in the two cases. But while the percentages are very nearly the same the fractions from the Beaumont oil are much heavier than the corresponding ones from the Pennsylvania oil, and up to the present there is no reason to believe that the fraction given off between 302° and 575° F. can be refined so as to be available for use in lamps. and therefore the chief field of usefulness for Beaumont oil will probably be as a fuel oil and a gas oil.

The residues left after the fractional distillation of the two kinds of oil also differ from each other very much. That from Pennsylvania oil contains paraffin scales and is not sticky enough to be pulled out in strings. That from Beaumont oil, although not strictly asphaltic, resembles an asphalt and is plastic. This residue amounts to about 6% by volume of the original oil.

As far as the determination of the nature of the hydrocarbons of which Beaumont oil is composed has gone, it has been shown to contain much larger quantities of unsaturated hydrocarbons and smaller quantities of saturated hydrocarbons or paraffins than the Pennsylvania oil, but the exact composition of these hydrocarbons has not been determined as yet.

SECTION III—MANUFACTURING PLANT. CONSTRUCTION AND OPERATION.

PART I—DISTINCTIVELY COAL GAS.

Charging, Drawing, and Coke Conveying Machinery.

23. Describe briefly and generally some method of charging and drawing gas retorts, in which hand labor is assisted by mechanical appliances, so arranged as to render the work easier and to enable it to be done by fewer men.

Ans. The appliances most commonly used for this purpose are those known as the West Manual Machines. The essential parts are a charging machine, a drawing machine, and a fixed overhead coal bin, from which a coal hopper on the charging machine is filled. There should also be an elevator of some kind to deliver the coal into the overhead bin, and provision must be made for reducing the coal used to a uniform size either by machinery or by hand.

The charging machine consists of a coal hopper and the charging apparatus proper, which are suspended in such a way, from a square upright frame mounted on wheels, that both can be easily raised or lowered together by a chain winch, and fixed at the proper height for charging each tier of retorts. The wheels supporting the frame run on rails laid on the charging floor in front of and parallel to the retort stack, and the whole apparatus can be moved along the stack by means of a hand wheel geared to the wheels of the frame. The hopper is made with the ends, or sides parallel to the stack, vertical, and the other two sides tapering to a long narrow opening at the bottom, through which the coal is fed by a four bladed feeder, revolving in a feeder box riveted to the under side of the hopper. The charger, a light carriage or box running on three wheels, is supported on a platform just below this feeder box, in such a manner that it is free to move in a direction perpendicular to the face of the stack. Its bottom is formed of a pair of semi-circular scoops, so pivoted and geared that they can be rotated in opposite directions through arcs of 90°, by simply twisting the long driving rod, thus forming an open space through which the coal can drop.

The operation is as follows: The charging machine is run under the overhead bin, filled with coal enough for all the retorts of the series about to be handled, the charger set at the proper height, and the machine moved into position in front of the first retort to be charged. A hinged flap is dropped forming a continuation of the charger platform into the mouthpiece. The operator then feeds the proper amount of coal for half a charge into the charger, by turning the feeder, pushes the charger to the back of the retort, twists the driving rod handle so that the scoops on the bottom of the charger rotate, and the coal drops on the bottom of the retort. The charger is then withdrawn, refilled, again pushed into the retort until it strikes the coal already there, emptied and withdrawn, the flap raised, the whole machine moved to the next retort and the lid of the first retort closed. When all the retorts of a series are charged, the machine is moved under the overhead bin and the hopper again filled in readiness for the next charge. A platform attached to the frame enables the operator to work to better advantage when charging the top tier of retorts.

The drawing machine is merely a frame on three wheels, which run on the rails used for the charging machine, carrying an adjustable arm for supporting the rake. This arm is so arranged as not to interfere with the use of a wheelbarrow or coke buggy under the mouthpiece, and is adjusted to the different tiers of retorts by means of a simple hoisting tackle attached to the frame. A platform for use when working the top retorts is fitted to this machine also. The chief object and advantage of the drawing machine is, that it takes the weight of the rake off the stoker, who can thus use a rake with a larger head and work more rapidly.

(For descriptions of other charging devices of the same class, see King's Treatise, Vol. I, pages 285 and 286, Journal of Gas Lighting, etc. (London) Vol. LXXIII, page 181, and Progressive Age, Vol. XV, page 427.)

24. Describe briefly and generally a system of charging retorts by machinery.

Ans. The Ross Discharging and Charging Machines will be described as an example of such a system.

The discharging machine carriage is made up of I beams mounted on wheels, and is driven with a small engine on rails laid upon the retort floor in front of and parallel to the benches.

On one side of the carriage are mounted an upright boiler, a water tank, feed pump, propelling engine, a horizontal engine, and a water cataract or governor.

Located transversely across the other side is a rectangular upright frame, the horizontal braces of which are the guides for the reciprocating traveler.

The rake bars can be raised or lowered at will and are guided by grooved rollers, and flat-faced wheels turning on studs to sustain and guide the rake bars, any one of which can be clamped to the traveler or to the rear columns when not in use.

The traveler is a hollow cast iron cross head riding between the guides upon duplicate grooved friction rollers above and below. The successful operation of the machine is due to the ingenious manner in which motion is given to the traveler. The steam cylinder is placed opposite to the water cylinder, both having a common piston rod, and each having a piston attached to the rod, somewhat similar to a steam pump. The two ends of the water cylinder are connected by a pipe with a valve in the centre, so that the flow of the water can be nicely adjusted. The water in the cylinder forms a cushion alternately at each end, thus preventing any shock or jar to the machine. On the piston rod between the steam and water cylinders is a rack, working a pinion which works a chain wheel on the same shaft, and this chain being attached to the traveler, operates the same, sending it backwards and forwards and carrying the rake to which it is attached with it. The possibility of any shock from the traveler against the end columns of the frame is avoided by rubber buffers, but the working of the machine is so easily controlled that it is seldom that they ever come in contact. The rake beams are of rolled angle iron, and the rake heads are steel castings suited to the shape of the retorts, and hinged to the ends of the rake beams.

The whole of the movements of the machine are governed by levers operated by one man, who is stationed at the extreme rear end out of the way of smoke or steam, and commanding a clear view of the interior of the retorts.

The charging machine consists of a rectangular carriage mounted on axles, to which are keyed the flange track-wheels. On one side of the platform are located the vertical boiler, steam reservoir, water tank, feed pump and disc engine for propelling. Upon the opposite side are located the charging hoppers, mounted in a vertical frame securely braced and supported upon axles, to which are keyed the wheels running upon rails laid across the platform of main carriage. Between these hoppers and the boiler is a steam cylinder for moving the hoppers back and forth, the motion being accomplished by a reciprocating movement imparted by a rack attachment to piston gearing, and a pinion to the shaft of which is secured a drum over which a wire rope coils in reverse directions. By the movement of a lever the hoppers are moved forward to the front of benches for the purpose of charging, or backward to the end of traverse rails for the purpose of refilling with coal from the storage bin. At the bottom of each hopper ten $\frac{3}{8}$ in. horizontal nozzles are connected, through which the steam is discharged in successive blasts against the coal, projecting it into the retort. The blast pipes are connected with a vertical 3 in. steam stand-pipe which is in turn connected to main steam pipe by a swivel-jointed connection, and a full way quick-opening valve, the handle of which is located within easy reach of the operator.

The steam reservoir serves as an accumulator to maintain the volume of steam necessary to give a uniform pressure during the operation of charging, and to relieve the boiler from any sudden strain or shock due to the quick opening of the valve. In the practical operation of charging, the machine is moved opposite the retorts previously discharged, the hoppers are filled from the storage bin and moved forward until the conduits enter the mouthpieces of the retorts and stop automatically at the proper point. The operator then projects the coal into the retort by quickly opening and closing the full-way valve three or four times. By the exercise of ordinary intelligence in graduating the duration and force of each blast, he can distribute the charge with as great, if not greater uniformity, than is ordinarily accomplished with scoop or shovel—the actual time occupied in charging three retorts seldom exceeding five seconds.

(For descriptions of other systems of charging retorts by machinery see answer to question No. 25 and American Gas Light Journal, Vol. LXVII, page 1004; Gas Manufacture, Hornby, page 48, and Journal of Gas Lighting, etc. (London) Vol. LXIII, page 957, and Vol. LXVIII, page 314.)

25. Describe one or more forms of steam, hydraulic, compressed air or electric machines for charging retorts.

Ans. The Bronder machine is one worked by steam. It consists of a carriage or platform mounted on wheels, running on a track laid on the charging floor of the retort house, in front of, and parallel to, the face of the retort stack. This platform carries a steam boiler, a coal hopper, a track at right angles to the main track, upon which run the wheels of a second carriage called the scoop carriage, and two steam engines, one for the purpose of moving the main carriage back and forth along the track on the floor, and the other for moving the scoop carriage, and the scoops attached to it, back and forth in a direction at right angles to the front of the stack.

Motion is communicated to the main carriage by means of an endless screw on the shaft of the engine, and a worm gear on one of the axles of the carriage. The engine is provided with reversing gear and also with a brake on its shaft for the purpose of slowing down and stopping the carriage.

The scoop carriage is driven by a chain or wire rope running around, and driven by, a drum mounted on the main carriage. After winding round the drum, one end of the rope is led to and around a pulley fixed at the front of the main carriage, and then brought back and fastened to the scoop carriage. The other end of the rope is similarly treated, except that the pulley around which it is led is fastened to the back of the main carriage. The drum itself is driven by the corresponding engine through an endless screw and worm gear. The engine is fitted with a reversing gear to which a tappet bar is connected, so that the engine is automatically stopped when the scoop carriage reaches the end of its travel in either direction.

The scoop carriage is provided with shelves or brackets for supporting the scoops, there being one for each scoop. There are usually three scoops arranged vertically, one over the other, at such a distance apart that each comes opposite the corresponding retort in the setting. Under each of the scoop supports are fixed two rollers, the tops of which protrude through openings in the supports, so that the bottom of the scoop rests upon them. Each scoop consists of a long box, or trough, built of steel and open at the top and front end. Resting loosely in the scoop and on its upper edges is a frame with angle iron sides and cross braces, which carries a series of scrapers. All of these scrapers, except the one nearest the back end of the scoop, are so fastened to the frame by pivots that their lower edges will swing forwards and upwards so as to allow them to pass freely over any coal in the scoop or retort when being drawn backwards, while they strike and rest firmly against the bottom of the scoop when being pushed forward. The rear scraper is rigid and forms the back end of the coal space in the scoop.

The scraper frame can be moved back and forth relatively to the scoop through a distance a little longer than that part of the scoop which contains the charge of coal. As the scoop with the coal is being pushed into the retort, and just before it reaches the limit of its travel, the lower end of a lever pivoted on the side of the scoop near the back strikes a stop fixed on the coal hopper, and is pushed backwards as the scoop moves on. As its fulcrum on the scoop is moving forward the upper end of the lever is given a forward motion, more rapid than that of the scoop, and since it rests against the back of the scraper frame this is pushed forward faster than the scoop, and the scrapers push the coal ahead of them and partly out of the scoop into the seat of the retort, this action taking place just before the scoop stops on reaching the end of its travel. When the scraper frame arrives at its extreme forward position a pawl, pivoted on the main carriage, drops behind the rear crossbars of the frame, and this with the scrapers is thus held stationary, while the scoop is being withdrawn from the retort. By this means the coal is held in place and drops on to the bottom of the retort as the scoop recedes, instead of being drawn backward with it. When the scoop has been entirely withdrawn from the retort, a trip piece on its side strikes an angular tappet piece so pivoted that as its lower end is moved back by the trip piece, its upper end raises the pawl and leaves the scraper frame free to move back. The mechanism which imparts the backward motion to the frame is contained in the back part of the scoop behind the coal space, and consists of a bar, a forward pulley fastened to the scraper frame, a rear pulley fastened to the scoop, and a rope which is fastened at one end to the rear of the scoop, passes forward around the pulley on the frame, back around the pulley fixed to the scoop and forward to have the other end fastened to the bar. This bar is free to slide back and forth in guides in the scoop. So long as the scoop and scrapers are traveling together this mechanism travels as a whole with them. When the scoop moves back, while the scraper frame is held stationary, the end of the rope fastened to the scoop, and the pulley also fastened to the scoop, move away from the pulley fastened to the frame.

To accommodate this motion, that portion of the rope passing around the pulley fixed to the frame must lengthen on each side of the pulley by an amount equal to the distance traveled by the scoop. This extra length can only be obtained by drawing on that part of the rope passing forward from the rear pulley on the scoop and fastened to the bar, which, since the bar is free to move, is practically a free end. The bar, therefore, is given a backward motion (in the same direction as the scoop) twice as fast as that of the scoop. This continues until the detaining pawl has been lifted, as described above. The continued movement of the scoop then immediately brings the end of the bar against a stop fastened on the main carriage, against which the rear end of the scoop also rests when it is at the extreme back end of its travel. The motion of the scoop still continues, but that of the bar being arrested, the end of the rope fastened to it is no longer a free end, and as the scoop moves back the rope is thus held at one end, while the other end, which is attached to the scoop, is drawn backward, as is also the loop passing around the pulley fastened to the scoop. The only part that is free to move to furnish the slack required to accommodate this double motion is the pulley fixed to the scraper frame, and this is accordingly drawn back, bringing with it the frame and scrapers at a rate of motion twice as fast as that of the scoop. The mechanism is so adjusted that when the scoop stops at the end of its travel the scrapers have reached their original position and everything is ready for another charge.

Both the scoop and the scraper frame are weighted at the rear end, the weight on the scoop serving to indicate when the proper weight of coal for the charge has been run into the scoop, and that on the frame acting as a counterweight to balance the portion which is left projecting into the retort as the scoop is withdrawn.

Either one, two or all three of the scoops can be locked either to the scoop carriage or to the main carriage. The scoops which are locked to the main carriage remain stationary when the others are run into the retorts, and in this case the rollers fixed to the scoop carriage, and on which the scoops rest, come into play to reduce the friction between the stationary scoops and the moving carriage.

The boiler and engine do not require any detailed description.

The coal hopper is divided into three equal compartments, each having a longitudinal opening the full length of the coal space of the scoop, and in such a position vertically as to allow the coal to be fed through it by a feeding device into the corresponding scoop. It is intended that it should be made large enough to hold all the coal required for the retorts to be charged at any one time.

The operation of the machine is as follows:

Two attendants are required; one to handle the traversing engine and the other to attend to the actual charging. When the machine is placed in front of the proper retorts the scoops are filled until the weight of the coal causes the front part to just balance the weight at the rear end, the forward rollers of of the two under each scoop acting as fulcrums. The scoop carriage engine is then started forward and the motion of the carriage carries the scoops attached to it into the retorts. Just before this forward motion is automatically arrested, when the front ends of the scoops have reached nearly to the back ends of the retorts, the accelerated forward motion is imparted to the scrapers so that the coal is pushed into the seat of the retort. As the engine stops and the carriage is brought to rest the detaining pawls drop and hold the scraper frames. The engine, which has stopped automatically, is then reversed by the attendant and the scoops withdrawn from the retorts, leaving the coal, which is held in place by the scrapers. The front ends of the scoop being lightened by the removal of the coal, are raised by the lowering of the counterbalance weights at the rear end and carry with them the scraper frame, raising the scrapers nearly clear of the coal. The continued backward travel of the scoops raises the detaining pawls, brings the bar of the scraper-withdrawing mechanism against the stop and then withdraws the scrapers, the engine being stopped automatically when everything is in its original condition at the back end of the travel of the scoop carriage. The main carriage is then moved opposite the next tier of retorts and the operation repeated, the process being continued until all the retorts have been charged.

West's charging machine is driven by compressed air. In it, as in the other machines described, the charging apparatus proper and a coal hopper are carried by a frame which can be moved along a track laid on the charging floor of the retort house parallel to the front of the bench. The machine has only one charging scoop, so that only one retort can be charged at a time, and this scoop and the coal hopper are so hung in the frame that they can be readily adjusted to the level of the retort to be charged. This adjustment is performed by means of the same compressed air motor by which the machine is propelled back and forth in front of the benches.

Attached to the bottom of the coal hopper is an adjustable measuring chamber to measure out the proper charge of coal. This chamber is made in two parts which telescope into each other and are held, by adjusting bolts, in the position desired with relation to each other, which is determined by the size of the charge. Sliding doors are provided at the top and bottom of this measuring chamber, and the levers actuating these doors are connected together in such a manner that when the doors at the top of the chamber are open those at the bottom are shut, while the latter cannot be opened until those at the top are shut.

The charging scoop is carried on a frame composed of side bars, in which runs the carriage for the gear by which the scoop is turned over, and of rails on which the scoop carriage runs when it is drawn out of the retort into position for filling. A movable flap is provided to form a bridge over which the scoop carriage can run between the rails on the machine and the retort. The scoop carriage is propelled into and out of the retort by means of a piston driven back and forth in a cylinder by compressed air. To this piston is attached a rod and rack which engages a pinion attached to the shaft of a chain drum. Around this drum are wound two chains which go out in opposite directions, and after passing, one around a pulley at one end of the frame in which the scoop carriage travels, and the other over another pulley at the other end of the same frame, are both attached to a double chain pulley fastened to the main scoop rod. They are passed around this pulley in such a way that at the proper time the scoop rod can be rotated either in one direction or in the other.

The charger scoop, which is usually made of a length equal to half of that of the retort to be charged, consists of two scoops supported on a carriage which rests on three wheels, two at the back and one just forward of the middle of the centre line between the scoops. The scoops are supported on the carriage by means of a longitudinal centre bar and end plates, the latter supporting the scoop shafts. At the end of the charger which first enters the retort each shaft is carried by a chain, one end of which is attached to the shaft at the point of the circumference which is lowest when the scoop is in position to be filled with coal, the other end being fastened to the fixed end plate. A loose plate carried on the ends of the shafts and free to move inside of the fixed plate closes this end of the scoops so that the coal cannot fall out. At the other end the scoop shafts are carried by a fixed plate and are provided with gear wheels engaging with gears attached to and driven by the rotation of the main shaft.

Each scoop consists of two parts which are capable of sliding concentrically over one another for a determined distance. One of these parts is rigidly connected to the scoop shaft so that it must rotate with this shaft, the other hangs loosely on the shaft and can be rotated around it. When the mainshaft is rotated the gears cause the scoop shafts to rotate also. Each of these shafts carries with it the portion of the scoop fastened to it. This slides inside of the loosely-hanging portion until its inner edge strikes against stops fastened to the latter. As the shaft continues to turn, the loosely-hanging portion is carried along by the other part until the shaft has completed a half revolution and the folded-together parts of the scoop are completely inverted. During this half revolution the chain from which the loose end of the scoop shaft is suspended has been wound round this shaft and the shaft has been raised so that, when the rotation stops, the inverted scoop is higher than it would have been had it turned about a fixed centre and it can consequently be drawn out without coming into contact with the coal deposited in the retort. The action described takes place simultaneously with both scoops, each turning in towards the middle of the retort so that the coal is dropped against the sides and into the corners.

The operation of the machine is as follows:

The coal hopper having been filled from an overhead coal bin placed in a convenient position in the retort house the machine is moved along the floor until it is opposite the retorts which are to be charged first. The height of the charger is then adjusted to that of the retort, the movable flap put into the mouthpiece and the measuring chamber filled with coal which is then run into the scoop. The attendant, by means of a lever which controls the valves, admits to the proper end of the cylinder which drives the charger, compressed air obtained through a hose and hose drum, so arranged that the hose unwinds from the drum as the machine moves away from, and is again wound up as the machine approaches, the drum. The piston being set in motion by the pressure of the air carries with it the rack which rotates the drum, winding up one chain and unwinding the other in such a way that the charger is propelled into the retort. Stops are arranged on the charger carriage frame so that the motion of the carriage will be stopped at the proper points. The piston continues to move after the motion of the charger is arrested and the pull on the chain rotates the main shaft, which causes the scoops to be rotated in their turn in the manner described above and the coal is deposited on the bottom of the retort. The double chain pulley, by which the main shaft is rotated, being prevented from turning by pawls, which are released when the pulley carriage comes against the stops by which the motion of the charger is arrested, this turning cannot take place until the scoop has reached the proper point in the retort.

The coal having been deposited in the retort, compressed air is admitted to the other end of the cylinder and the piston driven in the reverse direction. The chain pulley is held so that it cannot turn, and the first effect of the reversal is to withdraw the charger with the scoops inverted and clear of the coal as it lies in the retort. When the charger is back in place outside the retort, the pulley is released, and the scoops are rotated back into their original position and left ready to be again filled with coal.

The operation is then repeated, bringing into play an intermediate stop which arrests the travel of the charger at the proper point to deposit the second portion of the charge in the proper position in the front of the retort.

The machine is then moved along to the next retort to be charged and the series of operations repeated until the whole number of retorts to be handled at one time have been charged.

The West machine has been developed in England and it is only within the last few years that examples of it have been used in the United States. In these examples electricity is used as the motive power, instead of compressed air, and the scoop is made the full length of the retort, or portion of the retort, which it serves, so that the charge is completed with one trip of the scoop. A detailed description of the English type, fully illustrated, will be found at page 335 of Vol. LXXVII of the Journal of Gas Lighting, etc. (London).

The De Brouwer machine is driven by electricity. It differs from the machines already described in that no part of the machine itself enters the retort, the coal being projected into the retort by the velocity imparted to it by means of an endless belt. The machine is a very simple one. A frame, which can be either mounted on wheels running on rails set in the floor or suspended from wheels running on overhead-rails, carries a small coal hopper, a system of pulleys over which runs an endless belt and an electric motor by which motion is imparted to the driving pulley of the series. The belt is carried one quarter around a large grooved wheel, the belt being about 13 in. wide and the groove in the wheel 6½ in. wide and 4 in. deep. The belt, when it leaves this wheel, is traveling in a horizontal direction and continues so for a foot, when it turns downward over one of the small pulleys. It is then led back horizontally to a pulley which keeps it clear of the upper part and from there is led vertically up to and over the pulley which again brings it in contact with the large grooved wheel. The belt having been set in rapid motion by the motor-driven pulley, the coal is dropped from the hopper into the space enclosed between the belt and the grooved wheel, and is carried by the belt around the wheel and projected horizontally into the retort. The speed at which the belt travels is regulated to suit the distance to which the coal has to be thrown in order to reach the back of the retort, the longer the retort the higher being the speed employed. The coal, when it leaves the belt, possesses sufficient velocity to carry it to the back of the retort, and the first pieces of coal being stopped there the rest gradually fills the retort with an even layer from back to front.

More detailed descriptions of this machine will be found in the Journal of Gas Lighting, etc. (London), Vol. LXXXII, pages 367 and 523.

26. Describe one or more forms of steam, hydraulic, compressed air or electric machines for removing coke from retorts.

Ans. The Bronder machine is one worked by steam. It is composed of a carriage, or platform, and of the machinery required for doing the work of drawing the retorts, all of which is mounted on the platform. This is itself carried on wheels running in a track laid on the charging floor of the retort house in front of, and parallel to, the face of the retort stack. The same track serves for both charging and drawing machines, when both are used. On the platform are a steam boiler, an engine for moving the machine along the track, and the rake carrier and rakes for drawing the coke from the retorts, together with the mechanism for working the rake carrier. In some installations the boiler is omitted, the steam required for working the machine being obtained from the steam system of the gas works, through a flexible joint which permits of the travel of the machine from end to end of the retort stack.

The engine and mechanism for moving the machine, and stopping it at the proper points in front of the retorts, are similar to those used for the same purpose on the charging machine.

The rake carrier and the rakes, of which there are usually three arranged vertically one above the other, are carried on a framework consisting of two uprights, one at the back and one at the front of the platform, properly braced and tied together by horizontal members which form guides, on which run the rollers of the rake carrier. This carrier consists of two pieces of plate iron kept the proper distance apart by distance pieces. The four guide rollers are set between the plates, two bearing against the bottom of the upper guide and two running on top of the lower guide. The rake bars, or, as they might be called, the rake handles, pass between the two plates of the carrier and are attached to it by pins going through holes in both plates and in the rake bars which come opposite each other when the bars are in the proper position. If a rake is not needed, owing to the scurfing or repairing of a retort, it is disconnected from the carrier by pulling out the pin and is then fastened to the main carriage by a pin going through an extra hole in the bar and through a corresponding hole in a fixed plate fastened to this carriage. As the rakes are carried backward and forward by the motion of the carrier the bars run on rollers fixed to a frame, this frame being so arranged that it can be raised and lowered by means of a hand lever worked by the machine attendant. This permits of the rakes being lifted above the coke, as they are pushed into the retort, and dropped so as to engage with the coke and pull it out as they are withdrawn. To this frame a counterbalance is attached in such a manner that the position of the fulcrum, about which it works, is automatically varied to correspond with the extent to which the rake bars project beyond the frame so that the counterbalancing effect is always proportioned to the weight to be balanced.

Motion is imparted to the rake carrier from a piston working in the horizontal steam cylinder of a direct-acting reciprocating motor, the admission of steam to, and its exit from, this cylinder being controlled by suitable valve gear. The rod attached to this piston carries a hollow cross head, in which there is a pin, and upon this pin there turns freely a gear wheel which engages on one side with a fixed rack secured to one of the cross head guides, and on the other side with a flying rack which runs in, or on, the other cross head guide. As the cross head is moved back and forth by the action of the steam on the piston, it carries the gear wheel with it, and, as the teeth of this wheel engage with those in the fixed rack, the wheel revolves at the same time that its centre is being carried forward or backward and its circumference has therefore a lineal or longitudinal motion twice the length of that of the piston and cross head. This motion is imparted to the flying rack, every point of which thus moves twice as fast and as far as the piston. This rack carries two wheels or sheaves. A wire rope fastened at one end to the forward part of the main frame passes back to and around the front sheave, then forward to and around a sheave fastened to the front end of the main frame, and then back to be fastened to the rake carrier. Another rope starting from a fastening at the rear end of the main frame passes forward to and around the rear sheave on the flying rack, then backwards to and around a sheave fastened to the rear end of the main frame and thence forward to be in its turn fastened to the rake carrier. As the sheaves on the flying rack are moved, they give to the ropes passing around them lineal motion twice as great as that of their own centres, and this motion is transferred to the rake carrier. Since the sheaves move with the flying rack, which moves twice as fast and as far as the piston, it follows that the rake carrier, which moves twice as fast and as far as the sheaves, moves four times as fast and as far as the piston, and therefore the motion of the rakes over the full length of the retort is obtained with a comparatively small motion of the piston.

The longitudinal motion of the steam piston, and consequently of the rake carrier, is controlled by an hydraulic governor, consisting of a piston working in a water cylinder, the cylinder being arranged on the main frame in line with the steam cylinder, and the piston being attached to a rod fastened to the cross head, this rod being practically a continuation of the steam piston rod. The cylinder is counterbored for a short distance at each end to a diameter slightly larger than that of the piston. In each of these counterbored portions there is a small port opening into a passage which brings the two ends of the cylinder into communication with each other. There are also two more ports at each end opening from the body of the cylinder into this passage. The cylinder being filled with water and the piston working in it water tight, the rate of motion of the piston cannot be any greater than the rate at which the water can be transferred from end to end of the cylinder through the ports and the passage. As the piston approaches either end of the cylinder it covers first one and then the other of the ports opening out of the body of the cylinderand thus its speed is reduced gradually. The ports in the counterbores being always open the governor does not bring the piston to a full stop, but its speed is so reduced that its motion can be controlled by the steam valve without incurring any risk of knocking out the end of the retort. An enlargement in the water passage, forming an air chamber, provides for the space occupied, on one side of the piston only, by the piston rod, the excess water forced out of the side on which there is no rod and for which there is no room on the other side of the piston, owing to the presence of the rod, being retained in this chamber.

In operating the machine it is brought to the right point by the traversing engine, and the retort lids having been slacked off, the rakes are run forward into the retorts, being kept raised during their forward motion. When about one-third of the way back into the retorts the rakes are stopped, dropped into the coke and withdrawn, bringing out ahead of them the coke from the fronts of the retorts. They are then raised, run back a little farther than before, dropped and withdrawn, the operation being repeated until the rakes have reached the back of the retort and all the coke has been drawn out. The rakes are then brought back to their original position on the machine and this is moved to the next set of retorts to be drawn, and the whole series of operations repeated.

West's drawing machine, like the charging machine, is worked by compressed air. As made for large works, it is mounted on a separate carriage from the charging machine, but for medium-sized works both machines are mounted on the same carriage so that both can be operated by the same man.

In its separate form the machine consists of an upright frame mounted upon four wheels, which run on rails laid in the retort house floor, these rails being used in common by both the drawing and charging machines. This main frame is moved along the rails either by a hand wheel and gears or by a compressed air motor and gears.

Suspended from it in a position perpendicular to the face of the stack of retorts is a horizontal frame, made of channel irons, in which works the drawing rake bar. The chains supporting this frame are fastened, not to the frame itself, but to what may be called a cross head working in guides on the upright frame, and pass over pulley wheels at the top of the upright frame and then run down to a hand winch, by which the rake frame and rake can be raised and lowered to the heights of the various tiers of retorts. The rake frame is pivoted in the cross head so that the front end of it and the rake can be raised to let the rake pass over the coke as it makes the forward stroke into the retort and lowered to force the rake down into the coke and bring the latter with it as it is withdrawn.

The power for driving the rake back and forth and withdrawing the coke is furnished by a piston driven up and down in a vertical cylinder by means of compressed air admitted alternately above and below the piston. Fastened to the piston is a rod carrying a rack, the teeth of which engage in those of a pinion on the axle of a chain drum. To this drum two chains are attached in such a way that as one is wound up the other is unwound. The drum is made in two parts, one for each chain, which, while they move as one when the machine is in operation, can be moved separately in order to take up the slack of the chains when the rake is raised from a lower to a higher level and to pay out the chains when the rake is lowered. One chain runs from the drum down to, and partly around, a pulley wheel carried on the upright frame, then forward to, and partly around, a pulley wheel fixed on the forward end of the rake bar frame, and then back to be fastened to the back end of the rake bar. The other chain runs from the drum down to, and partly around, a wheel on the upright frame, then back to, and partly around, a wheel on the rear end of the rake bar frame and forward to be also fastened to the back end of the rake bar at the same point as the first chain.

Compressed air is brought to the machine by a flexible hose, and its admission to the cylinder is regulated by means of a valve chest and a slide valve. Five ports open into the valve chest, there being a separate exhaust and admission port for each end of the cylinder and an exhaust port opening to the outer air. The admission ports open into the cylinder next to the heads and each is provided with a check valve so set that it will open under pressure from the slide valve side and close when this pressure is removed, or a greater pressure is applied from the side toward the opening in the cylinder. The exhaust ports open into the cylinder at some little distance from the heads, so that as the piston nears the end of its stroke, in either direction, it closes off the corresponding exhaust port and is brought gradually to rest by the compression of the air still left in that end of the cylinder. The slide valve is an ordinary D-valve except that it contains a by-pass passage which puts the two ends of the cylinder in communication with each other, and thus permits the pressure to be equalized on both sides of the piston, when the valve is in its middle position. The valve is operated by a hand lever to which are connected two tappet levers for automatically putting it in its middle position just as the piston reaches either end of its stroke.

In operating the machine the rake bar is set at the proper height for the tier of retorts to be drawn, and the machine is moved opposite the first retort in the series. The operator, with one hand on the air-valve lever, moves this so as to admit air into the bottom of the cylinder. This raises the piston and revolves the chain drum so that the rake is pushed forward into the retort, the operator, by means of the rocking lever in his other hand, raising the rake above the coke. When it has gone in far enough he reverses the air valve, thereby first equalizing the pressure on both sides of the piston and then admitting air into the top of the cylinder, and at the same time drops the rake into the coke. The pressure of the air on top of the piston forces it down and moves the drum in the opposite direction, withdrawing the rake from the retort and bringing the coke with it. As the piston nears the bottom of the cylinder it shuts off the bottom exhaust port and compresses the air ahead of it until it is brought to a stop just as the tappet lever moves the slide valve to its middle position and allows the pressure to be equalized in both ends of the cylinder. The operator then pushes the valve over to admit air into the bottom of the cylinder and the process is repeated, the rake going farther into the retort at each stroke until all the coke is drawn out. When going in to the extreme distance on the last stroke, the air is cushioned ahead of the piston in the upper end of the cylinder just as is done at the bottom on each stroke. This cushioning at the bottom prevents the rake from being withdrawn clear of the retort, so a relief port is provided in the bottom head of the cylinder. This port is fitted with a valve, normally kept closed by the pressure in the cylinder, which, when the drawing of the retort is finished, is raised by the movement of a third lever. As the air escapes through this open valve the piston drops and the rake is completely withdrawn from the retort, and the machine can be moved into place in front of the next retort and the above operations repeated.

Sometimes a small water tank is placed on top of the upright frame and the water from this tank is allowed to run on the rake head to cool it when it is drawn out of the retort.

This machine was developed in England, and was introduced into one or two works in the United States about 1904; but in more recent installations in this country there has been used, in connection with the West charging machine, a ram driven by electricity, by which the coke is pushed out of through retorts—that is, retorts open at both ends. This ram is mounted upon the same carriage as the charging machine, and worked by the same operator.

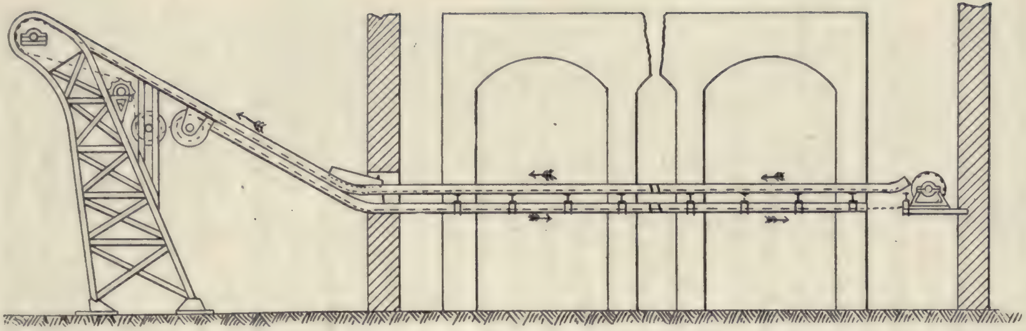
A similar ram is used as a companion machine to the De Brouwer projector.

27. Has any conveyor been successfully applied to receive the hot coke as it comes from the retorts and transport it to the coke yard, the coke being quenched in transit? If so, give a description of it, illustrated with sketches.

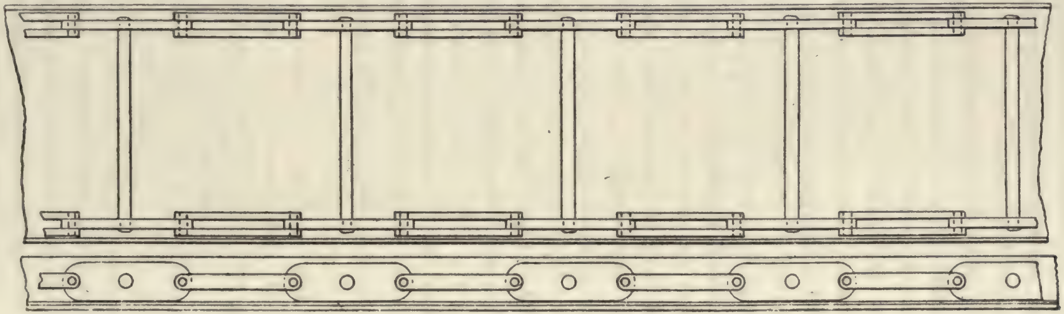
Ans. As far as is known at the present time (1903), only one gas company in the United States has had, with conveyors for the transport of hot coke, a satisfactory experience that has extended over a period of several years, although there are several companies that have recently installed conveyors for the purpose named. Almost all of these recent installations are examples of types of conveyors that have been developed in Europe. The experience of the company first mentioned has been such that an improved form of the conveyor used in an old retort house has been installed in a new retort house recently built.

This conveyor consists of interlapping pans made from soft steel sheets $\frac{3}{16}$ in. thick. Each pan is about 15 in. long and by their interlapping they form a continuous trough 20 in. wide and 6 in. deep of the length required to serve the stack. To the bottom of each pan is fastened one link of a chain designed so that any link can be easily removed as occasion arises and so that the wear at the joints between the links will be very slight. This chain passes over a friction driving wheel set at one end of the run and is driven by the friction between this wheel and suitable cylindrical bearing pieces provided on the chain. The working run of the pan is supported by wheels with horizontal axles, turning in fixed bearings and set in pairs, the proper distances apart, the whole length of the conveyor. To keep the wear caused by these wheels from coming on the pans themselves two narrow channel irons are riveted to the bottom of each pan, parallel to the driving chain and one on each side of it, and these channels form two continuous longitudinal grooves which rest on top of the wheels and also serve to guide the pan and keep it moving in a straight line. On the return the pan is guided by wheels with vertical axles, which bear lightly against the sides.

In this conveyor the coke simply rests in the pan and is carried along with it, so there is no friction between the coke and the metal bottom. The chain is kept entirely out of contact with the coke, reducing the wear upon it, and being driven by a friction wheel, instead of a sprocket wheel, slight increases in the length of link arising from wear do not interfere with the driving. The individual pans are very easily made by bending up the edges of flat plates of the proper size, and the parts upon which the wear comes can be very easily renewed, so that the conveyor is comparatively cheap in first cost and also in respect of cost of repairs. The Trustees have been unable to obtain sketches of this conveyor.



OUTLINE OF GENERAL ARRANGEMENT.
CONVEYOR FOR HOT COKE



DETAIL OF CHAINS AND CROSS-BARS.

Almost all the other conveyors in use with hot coke act by pushing the coke along a fixed trough by means of scrapers of varying forms. The one that has been longest in use is illustrated on the accompanying cut, and consists of a trough made of cast iron, wrought iron, steel or masonry, in which move two endless chains of special construction joined together by cross bars at intervals of about two feet. These cross bars also act as distance pieces and keep the chains parallel. The trough is either placed on the charging floor of the retort house or set in this floor with its top flush with the floor level. It varies in width from 20 in. to 2 ft. 9 in., the largest size being used for large installations of inclined retorts. The depth is usually 5 in., though the wide troughs can be made with a depth of 3 in., since most of the coke falls near the centre and very little reaches the sides. The bottom of the trough must be perfectly smooth so that there shall be no obstruction to the moving coke. The joints between the various plates composing the bottom and between these plates and the angle iron sides must be made water-tight, and the ends of the trough are turned up to retain the water for quenching, which is run into the trough continuously while the conveyor is at work. At the end at which the coke is delivered the conveyor may be, and usually is, run up at an angle of 30° with the horizontal to a height sufficient to allow the coke to be piled or dumped into wagons or cars, as it has been found that the coke can be easily carried up a trough at this angle.

The chains, which are driven by suitable sprocket wheels, are kept as near the side of the trough as possible, so as to keep them away from the coke and thus reduce the wear and tear. As shown on the cut these chains are made of solid blocks joined together by links formed of two flat bars, one each side of the solid links. The weight of the chains and cross bars is carried by the solid links and therefore all the wear comes on these links, which slide on removable wearing strips fastened to the trough in such a way that they can be easily renewed. The links are also so riveted together as to permit of their being easily disconnected.

It would seem at first sight as if the round cross bars of comparatively small diameter would not be efficient in moving the coke along the trough. In practice, however, they are found to carry the coke along perfectly, imparting to it a sliding motion without turning it over or crushing it. Their use keeps down the weight of the moving parts and also the friction, as compared with scraper or plate conveyors, and therefore this conveyor requires less power to do the same amount of work and there is less wear and tear on the bottom of the trough.

Another advantage claimed for it is that the return chain can be carried directly under the delivery trough, as shown, the total vertical space occupied being only from 8 to 10 in.

When commencing work the trough is partly full of water throughout its whole length, but the coke as it moves along pushes the water before it until the inclined portion at the delivery end is reached. After being partly carried up the slope the water flows back over the coke and thoroughly quenches it. It is thus found that comparatively little steam is generated until the slope is reached, and by having this outside the retort house the steam is kept away from the stokers.

As stated, this conveyor seems to have been thoroughly tested, and in the opinion of European gas engineers of good reputation has proved successful.

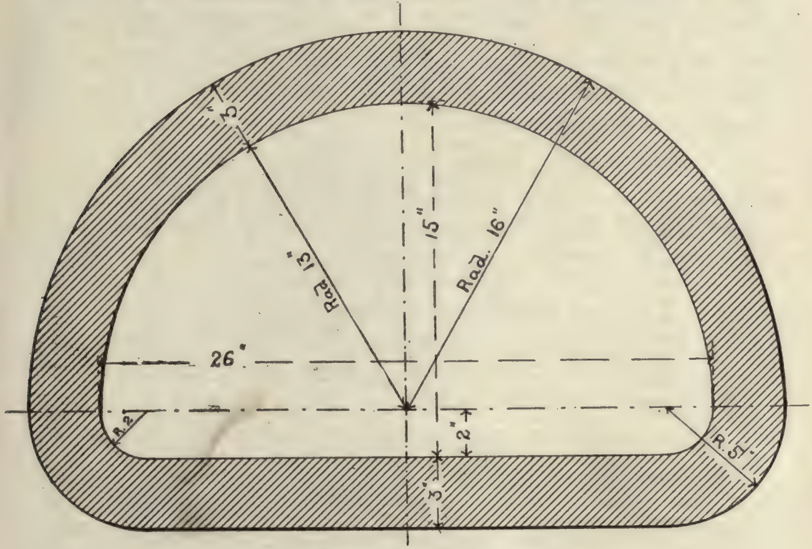
Several other forms which appear promising have been proposed recently in England, but have not yet had the test of long service. For a more complete description of the second form described by the Trustees, and also descriptions of other forms, the student should read a paper on Coke Handling Plant, read before the Institution of Gas Engineers, and published in the Journal of Gas Lighting, Etc. (London), Volume LXXIII, page 1349, and also in the American Gas Light Journal, Volume LXX, page 884. See also Journal of Gas Lighting, Etc. (London), Volume LXVIII, page 1235 ; Volume LXXI, page 1469 ; Volume LXXIV, page 767, and Progressive Age, Volume XVI, page 46.

Retort Benches.

28. Name the principal shapes of cross-section that have been adopted for clay gas retorts and give a sketch of the cross-section which you think the best. Show on the sketch the principal dimensions of the cross-section and the thickness of the retort walls. Give the reasons for your choice.

Ans. According to King's Treatise, clay gas retorts have been made with the following cross-sections: Square, square with rounded corners, round, oval and ∩ shaped. The last three shapes have been the most used, and in recent years round retorts have almost entirely disappeared, leaving only the oval and ∩ shapes in general use.

There is little to choose between these two shapes. In both the coal can be placed in the retort in a comparatively thin layer of uniform depth over its entire width, permitting of uniform carbonization. The oval retort is a little stronger sideways than the ∩, but in a well-built setting there should not be any great side strain on the retorts, and as the ∩ retort can be made with a semicircular top, it is better able to resist the vertical strains to which retorts are most



CROSS-SECTION OF CLAY RETORT.

liable to be subjected than is the oval, with its flatter top. It is easier to draw the coke from an oval retort than it is from a ⌓ shaped one with sharp corners, but this difference disappears when the ⌓ is made with rounded corners, and this shape, in the form shown on the accompanying cut, is probably employed in this country to a greater extent than the oval.

The walls of the retort are usually made 3 inches thick, with an increase to 4 inches or 4½ inches for about 9 inches to 12 inches at the front end, for the purpose of giving the strength needed for carrying the weight of the mouthpiece. In one large coal gas works in this country the retorts are made with walls only 2½ inches thick.

The dimensions of the cross-section should be governed by the amount of coal that is to be charged, and this depends on the heat that can be secured in the setting. It is bad practice to use in a setting that will not carbonize over 250 lb. of coal per charge the same size retort that is used in a setting that will burn off 350 lb. of coal per charge, lasting an equal length of time. In recuperative benches in which heavy charges can be used the cross-section is usually taken as either 15 in. × 26 in. or 16 in. × 26 in. At one large works, however, retorts of the latter size have been replaced recently by 16 in. × 24 in. retorts, and the change has resulted in the obtaining of better results.

29. The furnaces employed for heating coal gas retorts may be divided into two general classes. What are these classes, what is the distinctive difference between them, and what advantages has either one over the other?

Ans. The two general classes into which the furnaces employed for heating coal gas retorts may be divided are direct fire or plain furnaces and generator furnaces.

The distinctive difference between the two classes lies in the manner in which the combustion of the carbon in the fuel is effected. In the plain, direct fire furnace the carbon is burnt to carbon dioxide, CO_2, in the furnace, the combustion being completed in the fuel bed, while in the generator furnace the combustion is performed in two stages, the carbon being burnt to carbon monoxide, CO, in the furnace, this carbon monoxide being then burnt to carbon dioxide in a combustion chamber in the setting, into which a supply of air is introduced for this purpose.

The only advantage possessed by the plain as compared with the generator furnace is that of lower first cost, it being cheaper to build a setting with a plain furnace than it is to build one with a generator furnace.

On the other hand, to insure even approximately complete combustion of the fuel in the plain furnace the use of a large excess of air is necessary, the total amount required being two or three times as much as is theoretically necessary, while in the generator furnace where the air supply can be, and is, closely regulated, perfectly complete combustion can be obtained by the use of an amount of air not more than 10% to 15% in excess of the theoretical requirements. Since all the air passing through the furnace and setting must be heated to the temperature of the setting, the great reduction in the amount of air so passing, secured by the use of a generator furnace, permits the attainment of a higher temperature in the setting, when such a furnace is employed, and at the same time diminishes the amount of heat carried away from the setting by the waste gases, and therefore reduces the amount of fuel required to carbonize the coal.

The temperature in the furnace itself being higher in the direct fire furnace than it is in the generator furnace, the clinker formed is harder and the cleaning of the fire is a more difficult operation in the first class of furnaces, while the construction of these furnaces is such that a strong current of cold air flows through the setting during the whole time occupied in this cleaning. This cools the retorts and causes them to crack. The fire in the generator furnace can be cleaned without causing any such flow of cold air through the setting, and this style of furnace therefore possesses the further advantage of prolonging the life of the setting by maintaining it at a uniform temperature at all times.

30. What are the essential differences in construction and operation between non-generator (plain or direct fire) furnaces,

generator furnaces and regenerator or recuperative furnaces as used for heating gas retorts?

Ans. The essential differences in construction between plain and generator furnaces as used for heating gas retorts are in their size and location. The plain furnace is small, with a shallow bed of fuel, from 18 in. to 24 in. deep, and is located in the setting between the bottom retorts, while the generator furnace is larger, with a much deeper bed of fuel, this being 3 ft. deep in the case of so-called half depth furnaces, and 5 ft. to 6 ft. deep for full depth furnaces, and is entirely separate from the setting, being usually directly beneath it.

There are other important differences. The plain furnace is filled and cleaned through the same opening, which is closed by a loosely fitting door, while the generator furnace has an upper door for filling and a lower one for cleaning, both arranged to close air tight. No provision is made in the plain furnace for the control of the air supply except as this can be effected by the stack damper, while the generator furnace is so constructed that this supply can be carefully regulated.

The essential difference in operating is in the manner in which the fuel is burnt. In the plain furnace the carbon of the fuel is burnt at once to carbon dioxide, CO_2, while in the generator furnace there is a double combustion, first that of the carbon to carbon monoxide, CO, in the furnace proper, and then that of this carbon monoxide to carbon dioxide in the setting, by means of a secondary air supply. The direct combustion of the plain furnace requires a large excess of air, the total amount being two or three times that theoretically required, while in the generator furnace the air is carefully regulated, and need not be more than 10% to 15% in excess of the theoretical quantity required for perfect combustion. The volume of air to be heated being smaller, a higher temperature may be obtained in the setting heated with a generator furnace with a smaller consumption of fuel.

In both the plain and the generator furnace, the waste gases are allowed to escape to the chimney at a high temperature. The recuperative furnace differs from these in imparting to the air to be used for burning the fuel the heat in the waste gases, which are then discharged into the chimney at a low temperature. Thus there is carried back into the setting some of the heat lost in the operation of the other furnaces. In other respects there is no difference between generator and recuperative furnaces.

31. What are the principles of generator firing as applied to the heating of retort benches, and why is it possible to obtain greater economy of fuel with such firing than with direct firing?

Ans. The basic principle of generator firing for retort benches is the division of the combustion of the fuel into two stages. The first of these, brought about in the furnace proper, results in the formation of a combustible producer gas, and the second consists in the burning of this gas in a combustion chamber provided for the purpose in the setting. To secure the best results, both as to the temperature that can be attained in the setting and as to economy of fuel, the amount of chimney draft and the total amount of air supplied for the combustion must be closely regulated, and the proper proportion must be maintained between the portions of the total amount used for primary air, or air admitted into the furnace, and for secondary air, or air admitted into the combustion chamber, respectively. The amount of primary air should be such as to form a good producer gas containing a maximum of carbon monoxide and a minimum of carbon dioxide, and that of the secondary air should be just sufficient to secure the complete combustion of this producer gas.

When solid fuel is completely consumed in one stage it is difficult to secure intimate contact between the carbon of the fuel and all the oxygen of the air supplied for its combustion, and for this reason, to secure even approximately complete combustion of the carbon, it is necessary to pass through the fire an amount of air largely in excess of what would be required if all the oxygen could be brought into contact, and made to combine, with carbon. In practice it is found that in direct fired retort benches it is necessary, in order to secure approximately complete combustion of the fuel, to use, even under good conditions of working, between two and three times as much air as is theoretically required. The excess of air has to be heated up to the temperature of the furnace, and, since it is still highly heated when it leaves the setting, it carries away a large amount of heat which is thus wasted and the loss of which calls for the use of more fuel than would otherwise be necessary.

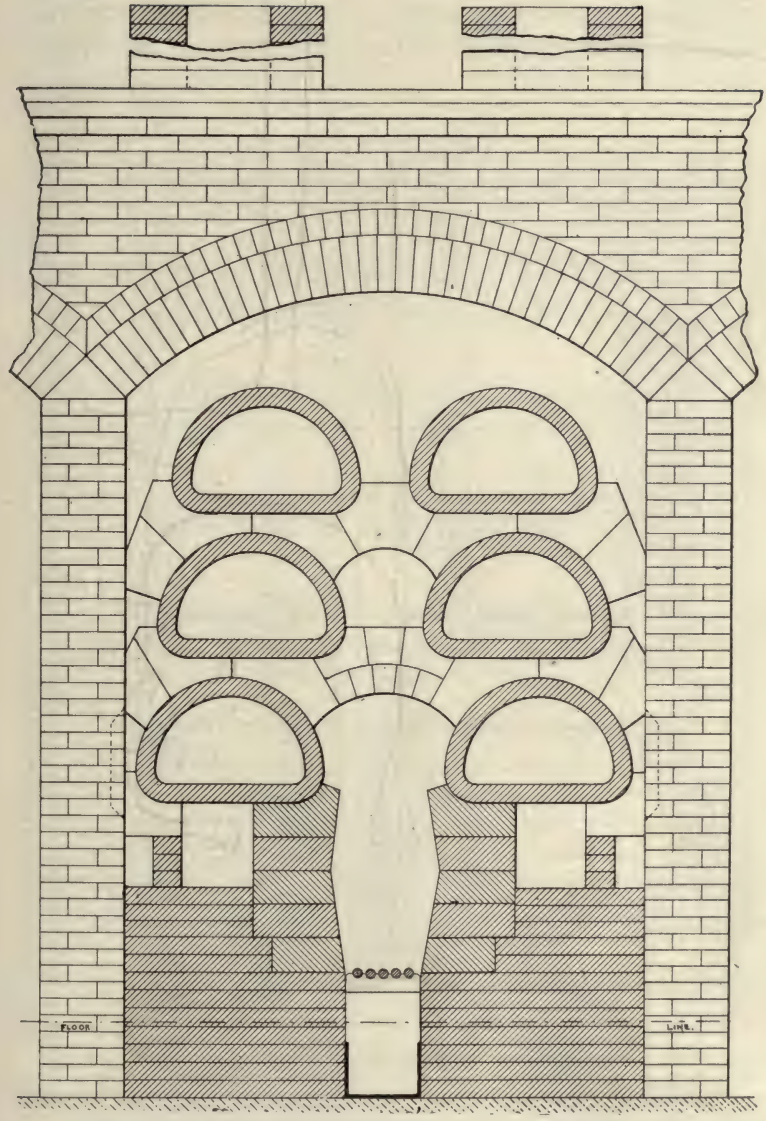
With a generator furnace only partial combustion of the fuel while in a solid state is desired, and this is effected with a limited supply of air, and the combustion is completed with the fuel in a gaseous state. In the case of a gas, intimate contact between the combustible and the oxygen of the air can be secured and the combustion can be made complete by the use of a very small excess of air over and above that theoretically required, this excess being as low as 10% of the theoretical amount. There is thus a much smaller quantity of extra air to be heated up to escape while hot, and enough heat is saved in this way to make quite a difference in the quantity of fuel required for a given amount of work.

With a generator furnace it is also possible to have the combustion take place in closer proximity to the retorts, and therefore to have the heat produced act more effectively upon them than can be done with a direct fire furnace, and this leads to a further saving in fuel.

32. Give a description, illustrated with sketches, of a bench of retorts equipped with a direct fire furnace and describe the operation of the furnace, paying especial attention to the manner in which the fire should be handled in order to secure the most economical results.

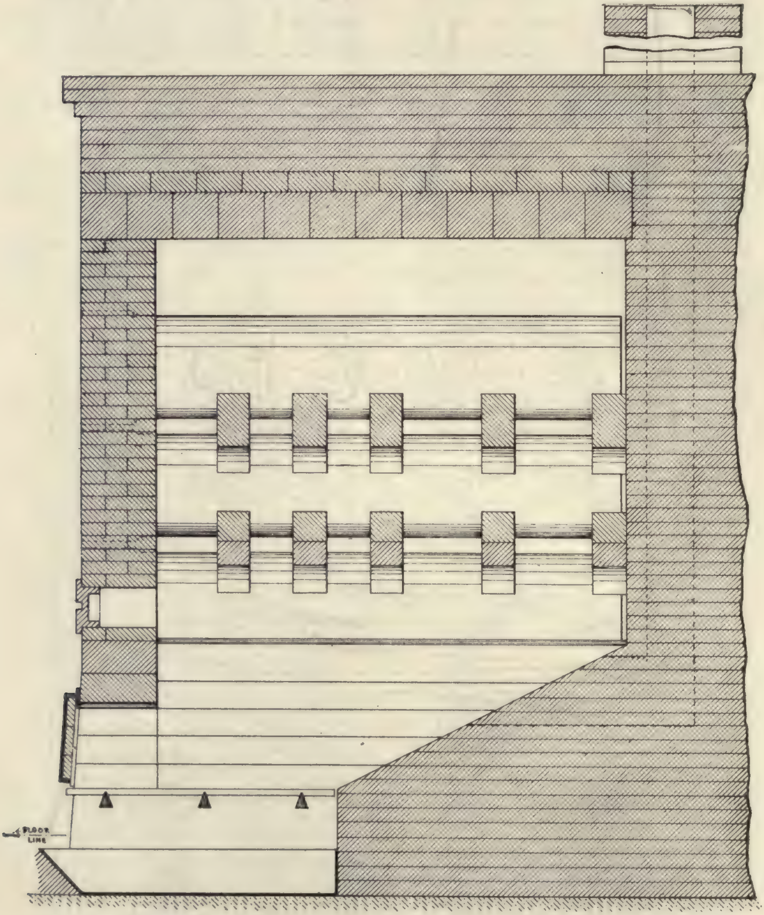
Ans. A bench set with six retorts heated by a direct fire furnace, is illustrated on the accompanying cuts, which show a vertical cross section, a vertical longitudinal section and a horizontal section through the flues carrying the waste gases from the setting to the chimney flues.

The setting, that is, the combination of retorts, furnace and flues, is built inside a space formed by two side walls, a back wall, in which are the chimney flues, and an arch springing



SETTING OF SIX RETORTS WITH DIRECT FIRE FURNACE.
CROSS SECTION.

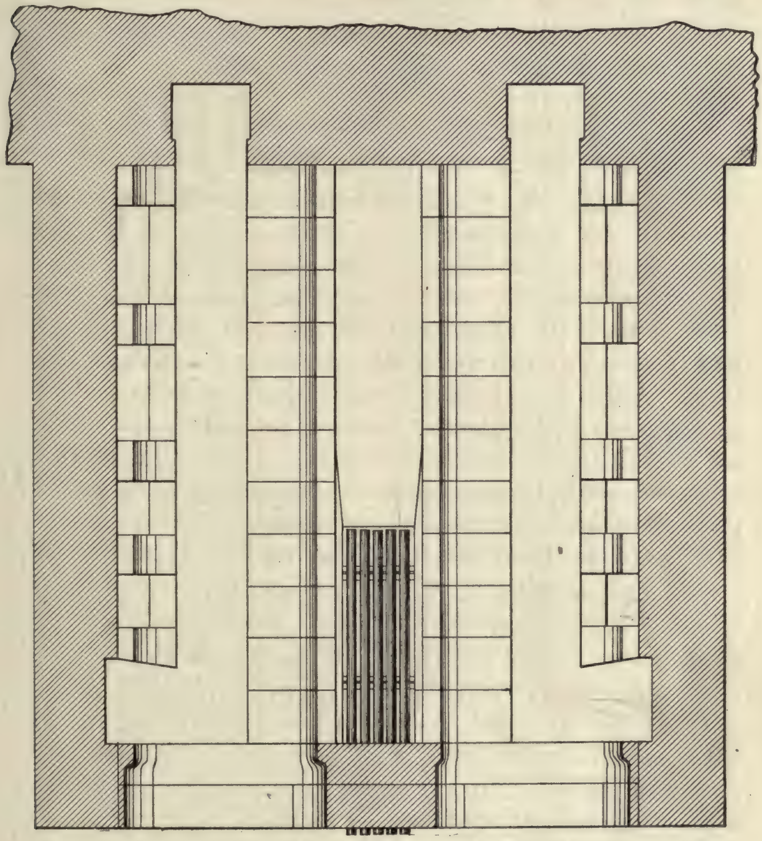
from the side walls and covered with brick work to a depth of about two feet. Such a space is called an "arch." The brick work of the setting and that of the "arch" are entirely



SETTING OF SIX RETORTS WITH DIRECT FIRE FURNACE.
LONGITUDINAL SECTION.

independent of each other, and the setting can be torn out and replaced at any time without affecting the arch.

As will be seen from the cross section, the retorts, which are D-shaped clay retorts 14 in. × 24 in. × 9 ft. 0 in. long inside, are set in two almost vertical rows of three each, placed symmetrically with respect to the middle line of the setting. The upper retorts are drawn closer to the middle line, for the double purpose of exposing them more directly to the radiant



SETTING OF SIX RETORTS WITH DIRECT FIRE FURNACE.

HORIZONTAL SECTION SHOWING BED FOR BOTTOM RETORTS AND THE WASTE GAS FLUES.

heat from the fire and of keeping their mouthpieces somewhat out of the way of the standpipes from the lower retorts.

Each bottom retort is supported on the inside, or side next the furnace, by blocks making a solid wall from the front to the back of the setting and constituting the top course of the furnace wall on that side, and on the outside by five blocks, each about 6 in. wide, one of which is placed at the back end of the retort while the others are spaced between this and the front wall, as shown on the horizontal section. All of these blocks are shaped to fit the retort.

The middle retorts are supported by five sets of blocks, of the same width as the blocks described above, spaced in the same way from the front to the back of the setting and resting on top of the bottom retorts, and the top retorts by similar sets of blocks resting on top of the middle retorts.

The furnace is built midway between the walls of the arch and with its walls parallel to these walls. At the grate bars it is 12 in. wide by 3 ft. 0 in. long and the width is increased to 18 in. at a point 17 in. above the bars and is then reduced to 14 in. at a height of 2 ft. 6 in. above the bars, which is that of the top of the walls between the bottom retorts. At the back it slopes from a length of 3 ft. 0 in. at the grate bars to one of the full depth of the setting at the top of the walls. Under the grate bars is an ash pan kept partly filled with water for the purpose of furnishing, by its evaporation under the influence of heat radiated to it from the fire, sufficient steam to prevent the clinker from becoming too hard.

The hot products of combustion rise from the furnace between the bottom retorts, after which part passes over between the top of the lower and the bottom of the middle retort on each side, while the remainder continues its upward course. Another part is taken off between the middle and the upper retorts and what is left is deflected over the tops of the upper retorts. All are finally drawn into the small side flues, which are situated, one on each side, next to the main flue under each bottom retort. By these side flues all of the hot gases, except a small part that is allowed to pass directly into the main flues by openings left underneath the retorts in the wall between the two flues, are brought to the front of the setting and then led back through the main flues to the chimney flues in the back wall. These chimney flues are continued up to a height of four or five feet above the top of the stack. The proportion between the amount of hot gases passing directly into the main flues and that brought forward to the front, can be regulated so as to have the retorts uniformly heated from front to back, by adjusting the size of the openings between the side flues and the main flues by the insertion, into these openings as originally left, of bricks introduced through the main flues. This is done after the bench is heated up.

After the retorts are all set the "arch" is closed in by a front wall of fire brick thirteen inches thick, built around the retorts with its face flush with their fronts. Sight holes, closed with removable plugs, are left in this wall at the proper points.

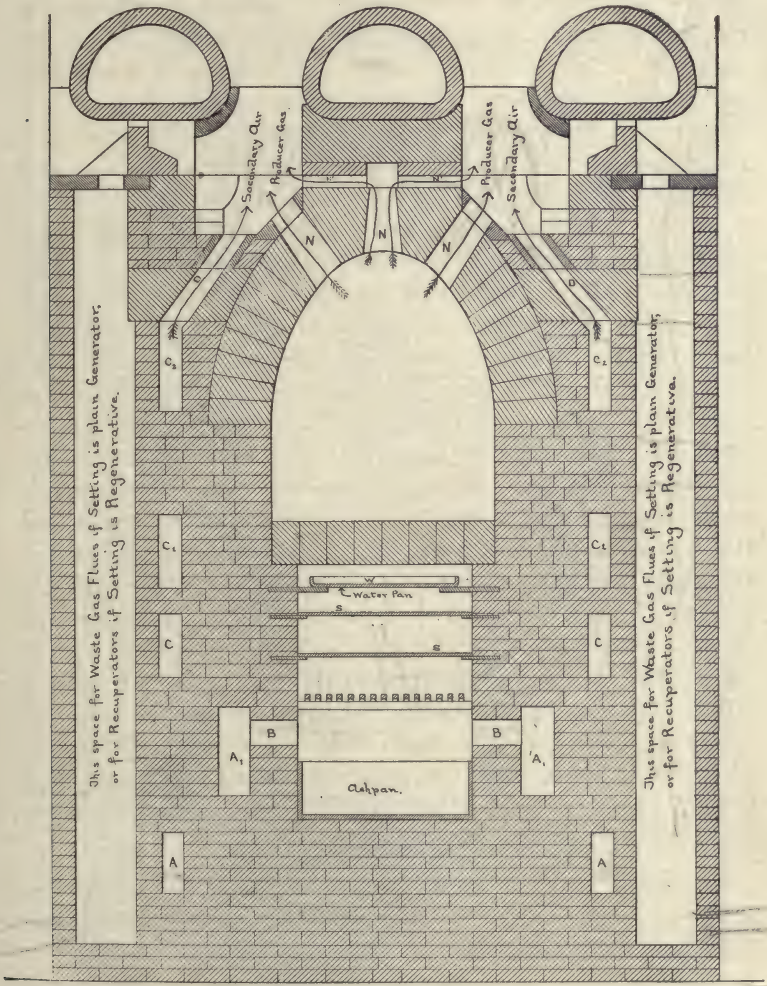
In a direct fire furnace the carbon of the fuel is burned to carbon dioxide, CO_2, in one operation, which is practically completed in the fuel bed, and the retorts are heated principally by the sensible heat possessed by the products of combustion passing off from the fuel bed. It is therefore necessary to so handle the furnace as to produce the highest possible temperature in the fire itself. In fact, the fire should be handled very much the same as a boiler fire. The bed of fuel should not be made too deep, a depth of from fifteen inches to eighteen inches giving the best results. Fresh fuel should be added at frequent intervals, about once every hour, in order to maintain this depth constant and keep the fire from burning down too low. The grate bars should be shaken lightly from time to time so as to keep the bottom of the fire bright. The condition of this part of the fire can be determined by observing the reflection shown on the water in the ash pan. About twelve hours after the fire has been clinkered a slice bar should be run along the grate bars and the clinker that has formed there should be thoroughly broken up. Clinkering must be thoroughly done every twenty-four hours. It is impossible to use secondary grate bars when cleaning a furnace of this kind, and so after pushing as much of the fuel as possible up on the slope of the back wall the rest is dropped into the ash pan by drawing away the grate bars, the clinker is cut away from the side and back walls and removed from the furnace, the grate bars replaced, the fuel on the back wall drawn down and spread over the bars and fresh fuel charged into the furnace. The wear and tear on the furnace walls can be reduced by leaving an inch or so of clinker on them at all times, never attempting to take it off down to the brick.

To secure economy of fuel it is necessary to prevent any air from being drawn into the setting through cracks in the brick work and openings around the frame of the charging door, and to be careful not to have an excessive draft. A direct fire furnace requires more draft to maintain the heat in the bench than does a generator furnace, but an excessive draft is bad in both cases. The appearance of flame at the top of the chimney flues indicates the existence of too much draft, and when it is noticed the dampers should be pushed in. All flues should be carefully cleaned out at least once a month in order to prevent any stoppages in them that would interfere with the keeping up of the heat, such stoppages being very frequently the cause of low heats when everything is apparently in good order.

33. Give a description, illustrated with sketches, of a generator furnace, either full depth or half depth, as applied to the heating of coal gas retorts. Pay particular attention to the points at which the primary and secondary air supplies are admitted, and the arrangements for filling the furnace, cleaning the fire and providing the steam required to keep the clinker soft, and do not omit sketches.

Ans. The accompanying cuts show a vertical cross-section and a longitudinal section of a full depth generator furnace, designed to heat a setting of 9 retorts. For a setting of 6 retorts the furnace would be made narrower and would have only one set of gas nostrils through the arch, this set being located along the centre line, but otherwise it would be the same. A half depth furnace would not be as deep as the full depth, but in other respects it would be practically the same.

This furnace is built directly beneath the setting which it heats. Its horizontal section is rectangular, 2 ft. 9 in. wide by 4 ft. 11 in. long at the grate bars, and increasing gradually to 7 ft. 5 in. in length at the crown of the arch 7 ft. 0 in. above the grate bars, while at a height of 2 ft. 0 in. above the bars an offset of 4½ in. on each side increases the width to 3 ft. 6 in. It is separated from the setting by an arch, the only communication between furnace and setting being through the openings or nostrils N, N, N, N, in the arch. As shown by the cuts there are in this case 15 of these openings in three rows of 5


Secondary Air
Producer Gas
Producer Gas
Secondary Air
N
N
N
D
D
C₂
C₂
C₁
C₁
C
C
W
Water Pan
S
S
B
B
A₁
A₁
Ashpan.
A
A
This space for Waste Gas Flues if Setting is plain Generator, or for Recuperators if Setting is Regenerative.
This space for Waste Gas Flues if Setting is plain Generator, or for Recuperators if Setting is Regenerative.

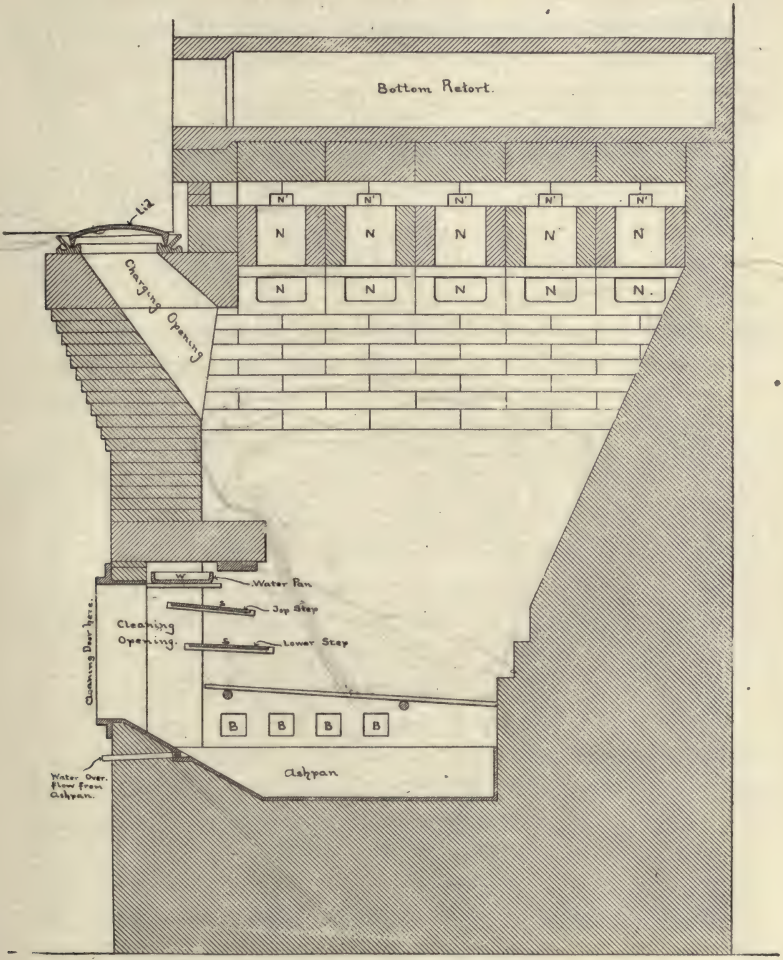
GENERATOR FURNACE.
VERTICAL CROSS SECTION.

each. One row extends along the top of the arch, and there is a row on each side a little down from the top. The arch is built of special arch blocks, but the rest of the furnace is built of fire bricks of the ordinary shape and size, those used for the inside lining being especially selected for hardness and ability to withstand the pounding and chipping of the clinkering bars, to which they will be subjected when the fire is cleaned. All the courses of the lining should be set as headers, since the brick if laid in stretcher courses will soon be cut through and knocked out of the wall by these bars.

The grate bars are made of wrought iron 1 in. square. Above the ordinary grate at the front of the furnace is what is known as a step grate. It consists of a cast iron water pan, W, placed above two steps formed of cast iron plates, S, S, both water pan and plates being supported by suitable brackets, built into the side walls of the furnace, in such a way that they incline towards the back of the furnace. The upper step projects beyond the inner edge of the water pan, and the lower step projects beyond the inner edge of the upper step. The function of this step grate is to supply, in connection with the ash pan, the steam required to keep the clinker soft and thus reduce the time and labor needed for cleaning the fire. For this purpose a small stream of water is kept running into the water pan over the inner edge of which it overflows, falling on the top step and running off of this to the lower step from which it falls into the ash pan. In this way a thin stream of water is exposed to the heat of the lower part of the fire by which it is evaporated, the steam so formed passing through the fire and reducing its temperature. The amount of water admitted must be carefully regulated.

Immediately in front of the grate is the cleaning opening, closed tightly by a self-sealing door which is opened only when the fire requires cleaning.

The charging opening, through which the furnace is filled with fuel, is in front at the level of the charging floor for the retorts, the brickwork of the front wall of the furnace being stepped out gradually until it projects enough to permit the opening to be entirely in front of the front wall of the setting, and in such a position that the coke from the middle retorts of a bench of 9s, or the top retorts of a bench of 6s, can be drawn directly into the furnace. This charging opening is closed by a loose cast-iron lid fitting into a groove in a cast iron frame so as to make an air-tight joint with the aid of a little coke dust which is allowed to collect in the groove.



GENERATOR FURNACE.
LONGITUDINAL SECTION.

The primary air is drawn in through two flues, A, A, one on each side of the furnace. The fronts of these flues are closed by air ports with slides by which the area of the opening and therefore the amount of primary air can be closely regulated. From these flues the air passes to the recuperators if the setting is recuperative, or direct to the furnace if the setting is not recuperative. In either case it enters the furnace through a number of openings, B, B, B, B, in the side walls directly under the grate bars, the object being to have it distributed as much as possible over the full depth of the grate.

The secondary air is admitted through air ports, similar to those for the primary air, into two flues, C, C, one on each side of the furnace, and passes through the recuperators, when these are provided, or simply through flues running to the back of the setting and forward again. In either case it is taken off from the last longitudinal flue in the series, by short transverse flues, D, D, D, D, each of which opens directly in front of one of the nostrils through which the producer gas passes from the generator to the setting. Each stream of gas is thus supplied with a stream of secondary air for its combustion. There are usually five of these openings on each side of the combustion chamber, as that part of the setting in which is begun the combustion of the gas is called, spaced equal distances apart from the front to the back of the setting.

To clean the fire, the water is shut off from the step grate, the cleaning door opened, secondary bars driven in above the top plate of the step grate until their points are supported by the sloping back wall of the furnace, the regular bars removed and the ashes allowed to drop into the ash pan, the grate bars replaced, the clinker cut away from the walls and removed, the secondary bars pulled out, dropping the fire on to the grate, the water turned on the step grate, the ashes removed from the ash pan, the primary air openings cleaned out, and the cleaning door closed to stay closed until the fire has to be cleaned again. If the coal contains only a normal amount of ash and the proper amount of water is supplied to the furnace, the cleaning need not be done oftener than once in 48 hours.

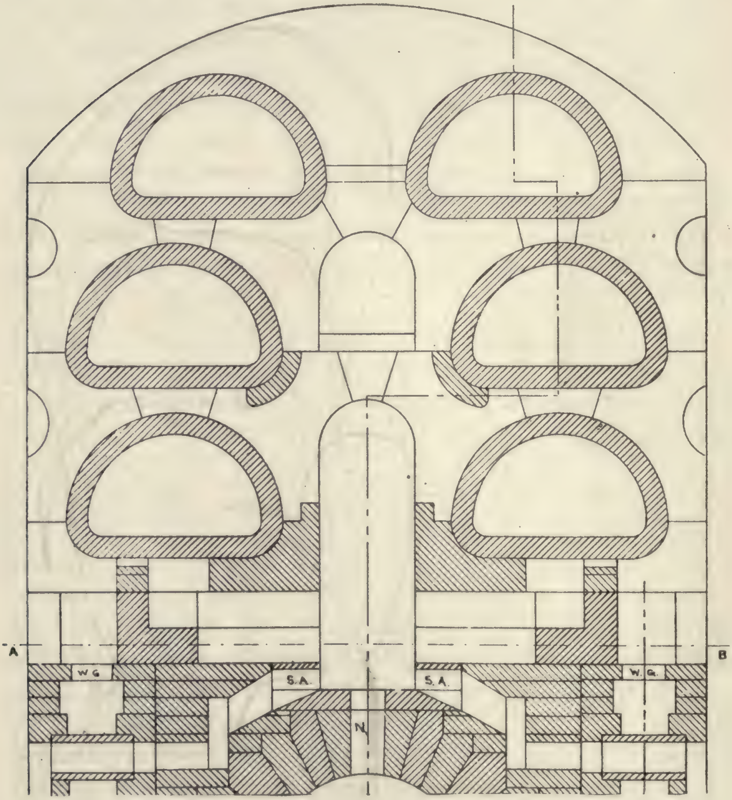
All generator furnaces are not built exactly as shown in the cuts, but every such furnace should have a closed top, and the arrangement of primary and secondary air flues and openings and of filling and cleaning doors will be substantially as is here illustrated and described.

34. Give a description, illustrated with sketches, showing a vertical cross section, a vertical longitudinal section and a horizontal longitudinal section, showing the nostrils in the furnace arch, the secondary air openings into the combustion chamber, and the openings through which the hot waste gases pass into the recuperators, of a setting of six retorts heated by a generator furnace and equipped with recuperators. Neither furnace nor recuperators need be illustrated except to the extent required to show the above mentioned openings.

Ans. The recuperative setting of six retorts, which is illustrated by the accompanying sections, is designed to be built in an arch 8 ft. 4 in. wide and to contain retorts, the inside measurements of which are 15 in. × 26 in. × 9 ft. 0 in.

As will be seen from the cross section, the combustion chamber is made wide and high, being 14 in. wide and 3 ft. 6 in. from the top of the furnace arch to the bottom of the first arch of the setting which crosses the combustion chamber. The producer gas enters this chamber by five openings, or nostrils, marked N, spaced equal distances apart from front to back along the centre line of the bench. The secondary air is admitted through the openings marked S. A. There are five of these on each side of the combustion chamber, level with the top of the furnace arch, each nostril having a secondary air opening opposite it on each side, so that two streams of secondary air are directed against each stream of producer gas.

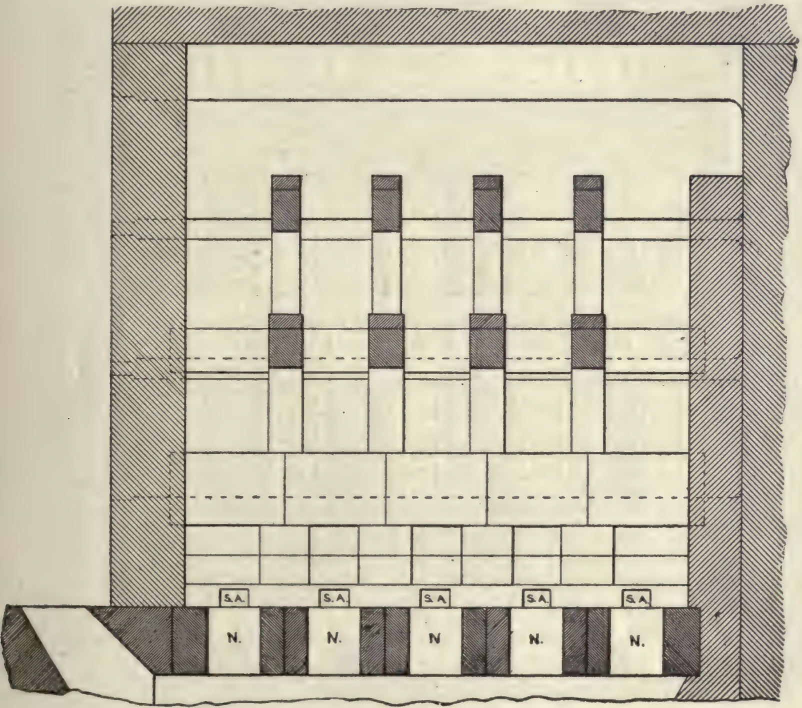
The setting is built in one single chamber, the combustion taking place and the hot gases passing up around the retorts along the full depth of the bench. To secure effective heating of the bottom of the bottom retorts, small passages, which lead out of comparatively large openings left under the bottom retorts, as shown on the sections, carry some of the hot gases directly from the lower part of the combustion chamber to the outside flues. The bulk of the products of the secondary combustion, however, pass upward and around the retorts, a portion passing out between the top of the bottom retort and the bottom of the middle retort, another portion passing out between the middle retort and the top retort, and the remainder going to the top of the setting and passing over the top of the top retort on each side. In whatever way the gases reach the space between the retorts and the outside walls on each



BENCH OF SIX RETORTS. RECUPERATIVE SETTING.

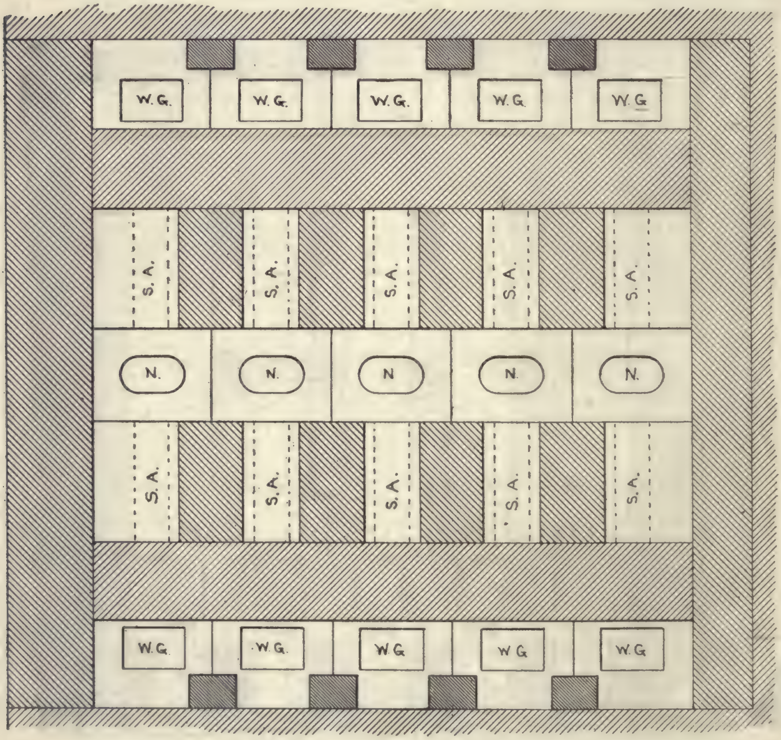
VERTICAL CROSS SECTION.

side, they are drawn down through this space to the bottom of the setting and pass down into the recuperators through five openings. These openings, marked W. G. on the sections, are spaced, like the nostril openings, equal distances apart from front to back of the bench, and by them an even distribution of the waste gases through the whole depth of the recuperators is secured.



BENCH OF SIX RETORTS. RECUPERATIVE SETTING.
VERTICAL LONGITUDINAL SECTION.

The setting is a skeleton one, no more bricks and blocks being used than are necessary to support the retorts and prevent the heat from passing out the front of the bench. For the latter purpose the front wall is made 13 in. thick. The retorts are supported at the front by this front wall, at the back by a wall 9 in. thick, and at four points between these walls by blocks made of the proper shape to fit the outside of the retorts and form supporting arches, which carry the retorts and relieve the lower ones of the weight of those above them. The blocks supporting the inside lower corners of the bottom retorts are made continuous for the whole length of the retorts so as to protect them from the great heat existing in this part of the setting and from the cutting action of the flame, and shield tiles are also provided for the inside lower corners of the middle retorts for the same object. At all other points the retorts are exposed to full contact with the products of combustion except where they are built in the front and back walls, or where they rest upon and are covered by the narrow supporting blocks. Since these blocks are only 5 in.



BENCH OF SIX RETORTS. RECUPERATIVE SETTING.
HORIZONTAL LONGITUDINAL SECTION ALONG LINE A B ON THE VERTICAL CROSS SECTION.

or 6 in. wide it will be seen that much the largest portion of the surface of the retorts is exposed to the direct action of the heat.

The blocks and bricks forming the walls of the combustion chamber should be made of extra quality material in order to stand the heat to which they are exposed. The blocks above the top of the bottom retorts on the inside of these retorts and all the blocks on the outside of the retorts may be made of any good first quality material.

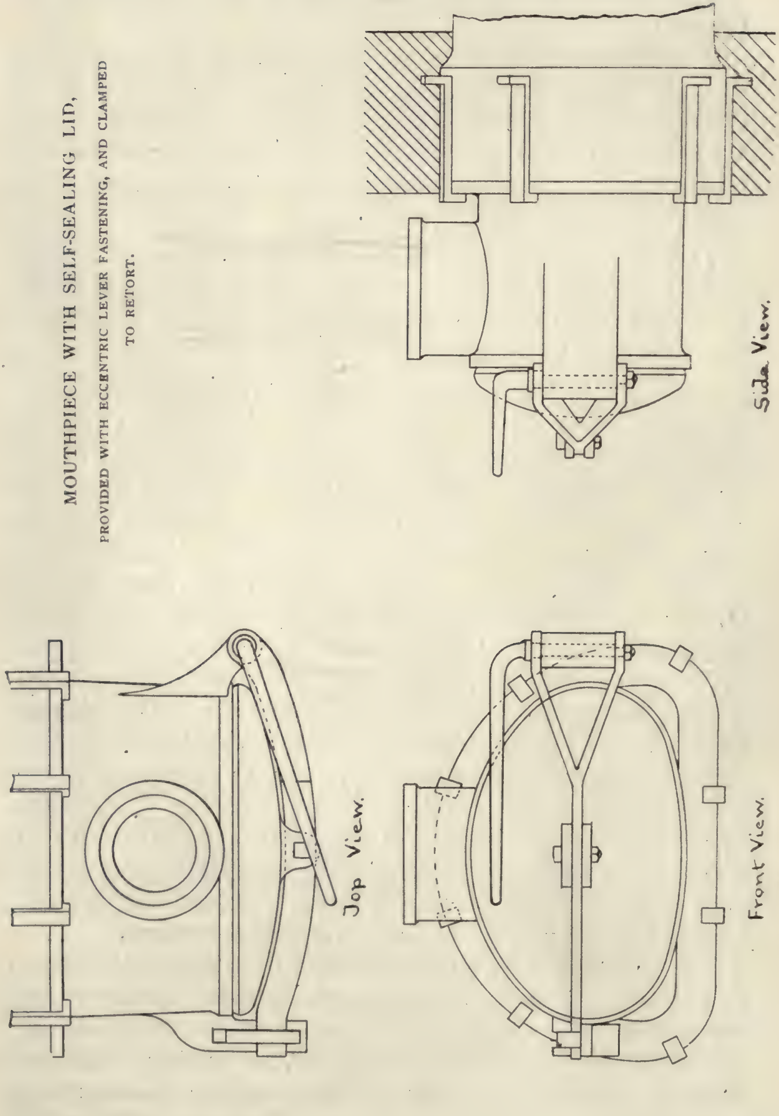
35. Give a description, illustrated with sketches, of a retort mouthpiece, showing the manner in which it is fastened to the front of the retort and the arrangement for making a gas-tight joint between the mouthpiece and the lid.

Ans. Retort mouthpieces are invariably made of cast iron, and such a mouthpiece may be described as being a tube of suitable cross section provided at one end with a flange of the size and shape of the front end of the retort and at the other with a faced lip, the cross section of the mouthpiece at this face being either round or more generally elliptical, no matter what the shape of the retort. The lugs required for supporting the lid and its fastening are cast on the sides of the mouthpiece, projecting beyond its faced edge, and an opening to allow the gas to escape from the mouthpiece is made at the proper place in the sides, at which place is also provided a bell to receive the lower end of the standpipe. The distance from face to face of flange and lip varies from 14 in. to 16 in., the shape and dimensions of the flange and the opening at the back should be the same as those of the retort, and the width and height of the front opening should also be the same as the corresponding dimensions of the retort, although the shape is, as stated, usually elliptical even with D shape retorts.

The mouthpiece is often fastened to the retort by means of $\frac{7}{8}$ in. bolts about 9 in. long, inserted in holes, parallel to the axis of the retort, made in that portion of the retort wall, at the front end, which is thickened for the purpose. Each of these holes opens at its inner end into a square recess extending in from the outside of the retort. A square nut is put in this recess, and the bolt, which is threaded at each end, is in-

MOUTHPIECE WITH SELF-SEALING LID,

PROVIDED WITH ECCENTRIC LEVER FASTENING, AND CLAMPED TO RETORT.



serted in the hole and screwed into the nut. The spaces left in the holes around the bolts are then filled with iron cement, made of one part by volume of fine iron borings or filings and two parts of fire clay moistened with a solution of sal ammoniac, the front of the retort is plastered with a layer of the same cement and the mouthpiece is put on and drawn up tight by screwing down the nuts put on the bolts. The faces of both retort and mouthpiece should be wet before the joint is made. A great objection to this method of fastening mouthpieces to retorts is that as the bolts burn out after the retorts have been in use for some time, the mouthpieces become loose and it is impossible to keep the joints between them and the retorts tight. It is also impossible to replace a broken mouthpiece by another in case of necessity. To avoid these faults clamps built into the front wall of the bench are often used either in conjunction with the bolts or to replace them. Some of these clamps are provided with set screws which screw down on the front of the mouthpiece flange, while others are merely bent over against this front. In any case it is advisable to have the mouthpiece flanges set into the front wall of the bench, the faces of flanges and brickwork being flush with each other. When this is done the brickwork affords a good support to the mouthpieces apart from the fastenings while no injury is done the flanges.

The joint between mouthpiece and lid was formerly made by means of a clay luting, but in recent practice by facing the front of the mouthpiece as described above and making the lid with a V shaped edge, which is also faced, the lids are made self-sealing. The lid is pressed against the face of the mouthpiece either by a cotter bar and screw or by a cotter bar with an eccentric lever handle. The latter form is the one most frequently used. When it is employed, the lid is provided with two lugs cast on it with their vertical centre lines coinciding with that of the lid and one above and one below the horizontal centre line of the lid with sufficient space between them to take the cotter bar to which it (the lid) is fastened by a pin passing through both lugs and the bar. On one side of this fastening the cotter bar branches into two parts with flat circular ends which fit on either side of a lug cast on the mouthpiece. Through this lug and the two parts of the cotter bar passes a pin by which the lid is fastened to the mouthpiece. This pin is turned and the openings in the cotter bar and lug are bored to make the pin a snug fit. The portions of the pin passing through the two parts of the cotter bar are turned to a common centre, but that passing through the lug is turned eccentric to the others. A lever handle is welded to the pin, and by this handle the pin can be revolved in the lug and cotter bar. The other end of the cotter bar is single and is caught and held, when the lid is shut, by a hook fastened to a lug on the opposite side of the mouthpiece from the hinge lug. This end being held fast, the eccentricity of the different portions of the hinge pin causes the cotter bar to be thrown toward the face of the mouthpiece, when the pin is turned in the proper direction, and thus presses the lid against the mouthpiece with sufficient force to make the joint gas-tight. The centre pin which passes through the lugs on the lid and through the cotter bar is also made eccentric and thus furnishes an adjustment by which the pressure produced by the action of the main eccentric can be regulated.

36. What points are to be provided for in designing the standpipes, bridge pipes and dip pipes for a bench of coal gas retorts?

Ans. The most important thing to be provided for in designing the stand pipes, bridge pipes and dip pipes for a bench of coal gas retorts is that they shall be made so that every point in each of them can be reached with a cleaning tool having a diameter not more than ½ in. smaller than that of the pipe. To enable this to be done the bent pipes must be made with very gradual curves and without any abrupt changes of direction and the dip pipes should be made perfectly straight from the cleaning opening on top to the lower end dipping under the water in the hydraulic main. If abrupt curves are used, it will be impossible to keep the pipes clear and free from stoppages.

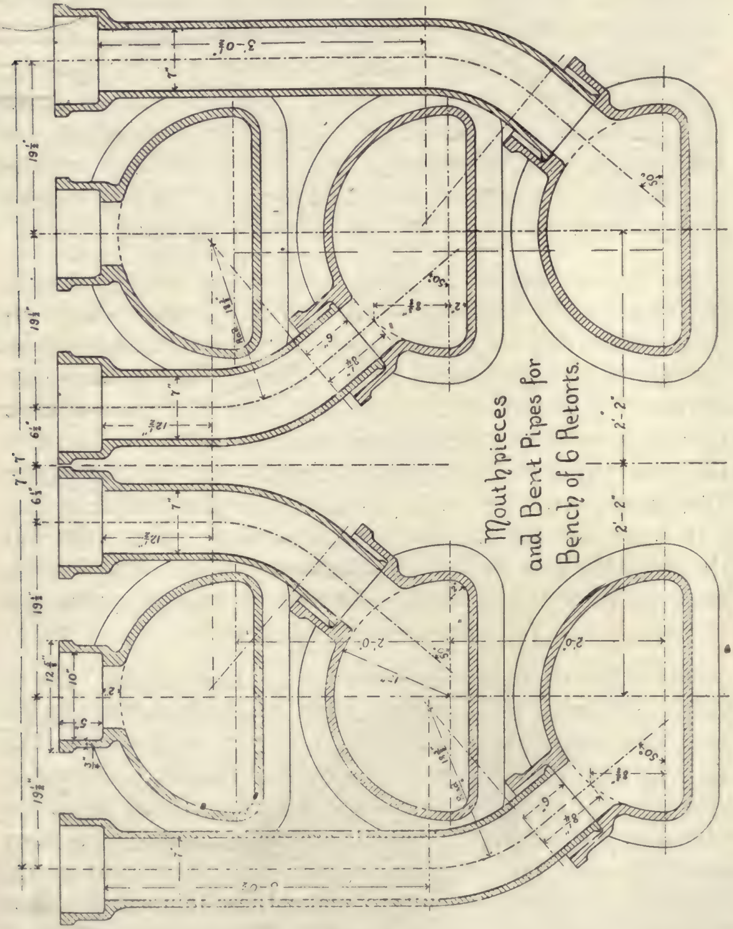
It is also well to keep the number of joints down to a minimum, as the breaks in the surface at joints afford an opportunity for the building up of obstructions.

If the above points are observed, the necessity of having the pipes of large diameter is not as great as it is sometimes thought to be, pipes 7 in. in diameter being amply large for retorts carbonizing 350 pounds of coal in four hours.

It is understood to be a matter of course that the pipes will be provided with flanged joints, at such places as to enable them to be easily removed and replaced when necessary, and with proper cleaning openings, while the question of whether cast iron or wrought iron is to be used for the standpipes is such an open one that it will not be taken up here.

37. Give a drawing showing, by a section through the centre lines of the bent pipes, the layout for the bells on the mouthpieces and for the bent pipes for a bench containing six retorts, of the cross section given on the cut accompanying the answer to question No. 28, set in two vertical rows of three each, the centre of the retorts in each row being 2 ft. 2 in. from the centre line of the bench and 2 ft. 0 in. apart vertically. The pipes are to be 7 in. in diameter. The hydraulic main is 9 ft. 6 in. long over all and has a 3 in. angle iron at each end, the space between these angles being 9 ft. 0 in. The drawing must be fully dimensioned. Give also a written explanation of your reasons for adopting the design shown.

Ans. One of several possible ways of making the bells on the mouthpieces, and the bent pipes, for the bench of six retorts described in the question, is shown on the cut. The mouthpieces are designed to be the full size of the retort all through, this being very necessary for retorts that are to be drawn by machinery. The bells are made large so as to leave plenty of room for the joints around the spigot ends of the bent pipes, it being difficult to make these joints tight when the space left for them is too small. The curved portions of the bent pipes themselves are made with as large a radius as it is possible to have on the two which pass up in the space between the top mouthpieces. This radius being sufficiently large to give a good sweep, has also been adopted for the pipes passing outside of the top mouthpieces in order to have all the bends the same, and so save pattern work, even though here a longer radius could have been used. The part of each bent pipe which enters the bell has been made straight to make it easier to secure a good joint. The different bent pipes have been made of such lengths as to bring all the bells into which the standpipes enter, including those on the top retorts, on the same level, since this gives to the front of the


Mouthpieces and Bent Pipes for Bench of 6 Retorts.

bench a much neater appearance than it has when these bells are at different heights.

If wrought iron standpipes are to be used, the diameter of the bells on the top mouthpieces and bent pipes can be reduced a little, if desired, and for the sake of simplifying the construction and reducing the weight of the mouthpieces some engineers make them without bells, providing instead seats to which the flanged ends of the bent pipes, or of short flanged bells for the top retorts, can be bolted.

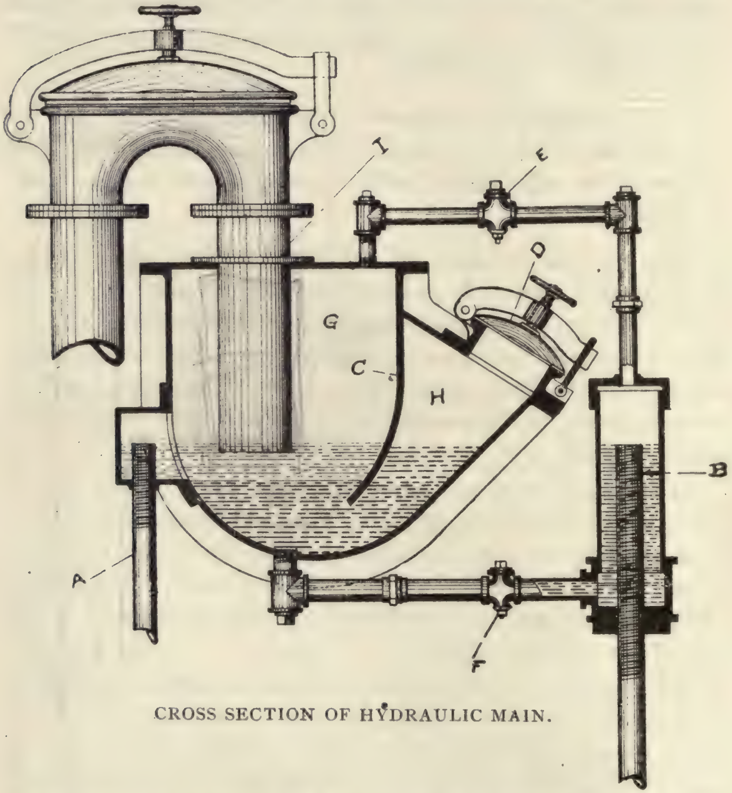
38. Draw a cross section of a hydraulic main showing one dip pipe, the level of the liquid in the mains, and the overflow, if it is on the side of the main. Describe the main, and its action and care.

Ans. The accompanying cut will illustrate the principle upon which a hydraulic main of modern construction is operated. It represents a cross section of a diaphragm main, and, while not drawn to show the exact construction of any main with which the Trustees are acquainted, it is drawn to illustrate as accurately as possible the principle upon which these mains operate.

Referring to the cut, A is the liquor overflow ; B the tar overflow ; C the diaphragm, which extends from end to end of each section ; D a cleaning door, of which there may be several on each section ; G the gas space in the main ; H the space through which the main is cleaned, as described below, and F and E are ordinary cocks.

The purpose of this construction is to enable the operator to draw the tar off from the bottom of the main, the liquor being drawn from above the surface of the tar ; and to provide that the gas entering the main from the dip pipe I bubbles through the liquor, and does not come in contact with tar. The heavier shading shows the tar in the main ; the lighter shading, the liquor.

It is desirable to keep the tar so low in the main that the gas from the dip pipe will not come in contact with it. The top of the liquor pipe A must be on the level at which it is desired to keep the surface of the liquor, and will be as much above the bottom of the dip pipe as it is desired that the dip pipe dip into the liquor. Therefore, in arranging the overflows for tar and liquor, it is first important to screw up the pipe A until its upper end is at the point at which it is desired to maintain the surface of the liquor. If it is desired to carry 1 inch seal, the upper end A will be 1 inch above the lower



CROSS SECTION OF HYDRAULIC MAIN.

end of the dip pipe. The tar outlet B is then screwed down until its upper end is somewhat below the upper end of the liquor overflow A. The lower the tar overflow is set, the greater will be the distance between the bottom of the dip pipe and the tar in the hydraulic main. The limit to which the tar overflow can be lowered is determined by the differences in the gravity of the liquor and the tar, and this will vary with the different coals, different temperatures of retorts, and somewhat with the temperature conditions surrounding the main. It is not considered important that the tar should be more than 4 inches or 5 inches below the end of the dip pipe. This condition can be secured by setting the tar overflow from 1 inch to 1½ inches lower than the liquor overflow. As long as liquor continues to flow out of the overflow A, the tar overflow B is not too low.

It will be readily seen that the tar overflow B can be lowered to a point at which all of the liquor and tar from the main will flow through it, leaving the liquor overflow above the level of the liquor in the main, and reducing or entirely removing the seal of the dip pipe.

It may happen that there will be an accumulation of very heavy tar or pitch at the bottom of the main that will be so sluggish in its flow that the tar will cease to overflow through its provided outlet B, and all the tar and liquor will flow out through A. When this occurs, or when, for any other reason, it is desirable to clean the main, the cleaning doors D are opened, and scrapers used to draw the tar and pitch up the incline through H, and through the doors D. This can be done while the main is in operation, as the diaphragm C, dipping down into the tar in the main, prevents the gas from escaping, even when the door D is open.

When the main is used, the cocks E and F should be open.

39. Give a description, illustrated with sketches, of one length of hydraulic main for benches of six retorts, including the dip pipes, overflow or overflows, arrangements for cleaning out heavy tar or pitch, and the considerations that determine the area of the surface of liquor in the main outside of the dip pipes.

Ans. The hydraulic main for a bench of coal gas retorts should be made of wrought iron. The cross section shown on the accompanying cut is one of several that are in use. The length of a section would be just a little shorter than the distance between centres of the division walls on each side of the bench, and its width would be such as to give the necessary area of surface of liquor outside the dip pipes, the manner in which this area is determined being explained later.

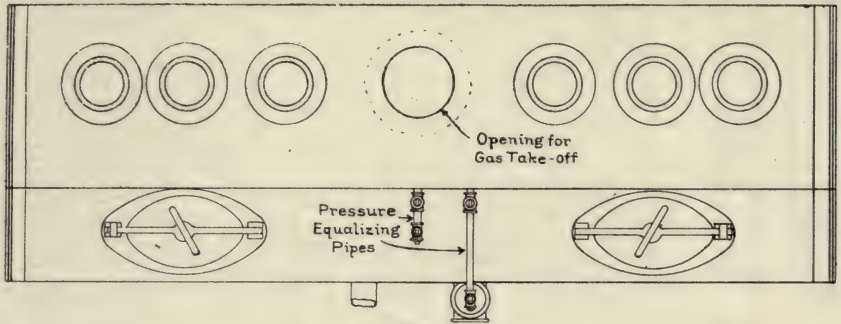
Circular holes are cut at the proper places in the top plate for the insertion of the dip pipes. These pipes must all be made exactly the same length from bottom of flange to lower end of pipe so that these ends will all be the same distance below the top plate, and will therefore all be sealed to the same depth when the main is set level.

The plate A serves to seal the space between it and the back plate B from the body of the main and thus permits the opening at any time of the cleaning lids, of which there are at least two to each length of main, for the drawing out of heavy tar, which is too thick to run off through the tar pipe, without interfering in any way with the process of gas making. The same end may also be attained by making the body of the main U-shaped and attaching to it, on the back, cleaning pockets, the openings in the side of the main being made with their top edges below the water line to seal off the pockets from the main so that cleaning can be done at any time without interfering with gas making. The side of the main or of the pocket, as the case may be, along which the tar is to be drawn should be given a gradual slope in order to make it easier to draw out the heavy tar.

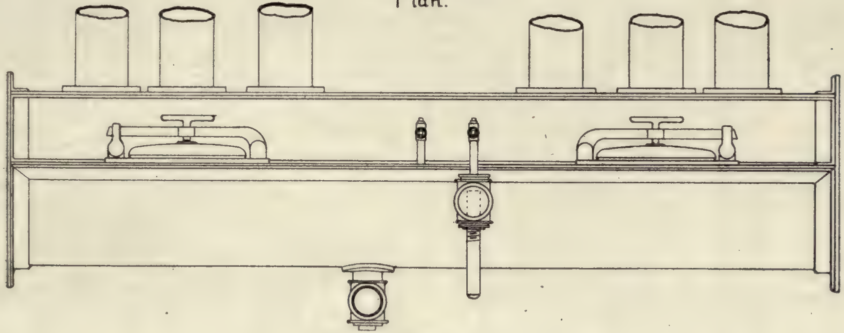
The overflows are arranged in various ways. Sometimes a single overflow, opening from the bottom of the main, is used to draw off both the tar and the ammoniacal liquor deposited in the main ; in other instances only the liquor is drawn off by an overflow, the tar being run off at intervals through a drain pipe, while still another arrangement is to have two separate overflows, one for the liquor and the other for the tar. This last is the best arrangement, the objection to the single overflow for both tar and liquor being that it does not maintain a uniform seal on the dip pipes, while running off the tar at intervals entails a certain amount of labor that is avoided by the double overflow, so long as the tar is kept thin enough to run out of itself. Such an arrangement is shown on the cut. In every case the overflows should be made adjustable as to height so that the seal can be varied to suit different require-

HYDRAULIC MAIN

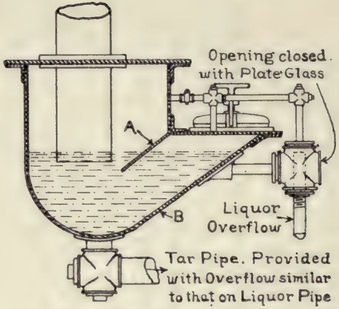
FOR BENCH OF SIX RETORTS.



Plan.



Elevation.



Section.

ments. The adjustability is usually obtained by the use of nipples with long threads which can be screwed up or down inside of a suitable fitting. For the liquor overflow a 1½-inch pipe screwing into a bushing set in one outlet of a 3-inch cross may be used. Special weir valves are also made for this purpose. When the overflow opens out of the main below the water level, as is often the case, a connection must be made between the gas space in the main and the space above the liquid in the portion of the overflow outside of the main, so that the pressure on the surface of the liquid in the main and that on the liquid in the overflow shall always be the same. Otherwise the main might be partially emptied of its liquid contents if a heavy pressure was thrown upon it by the stoppage of the exhauster or in any other way.

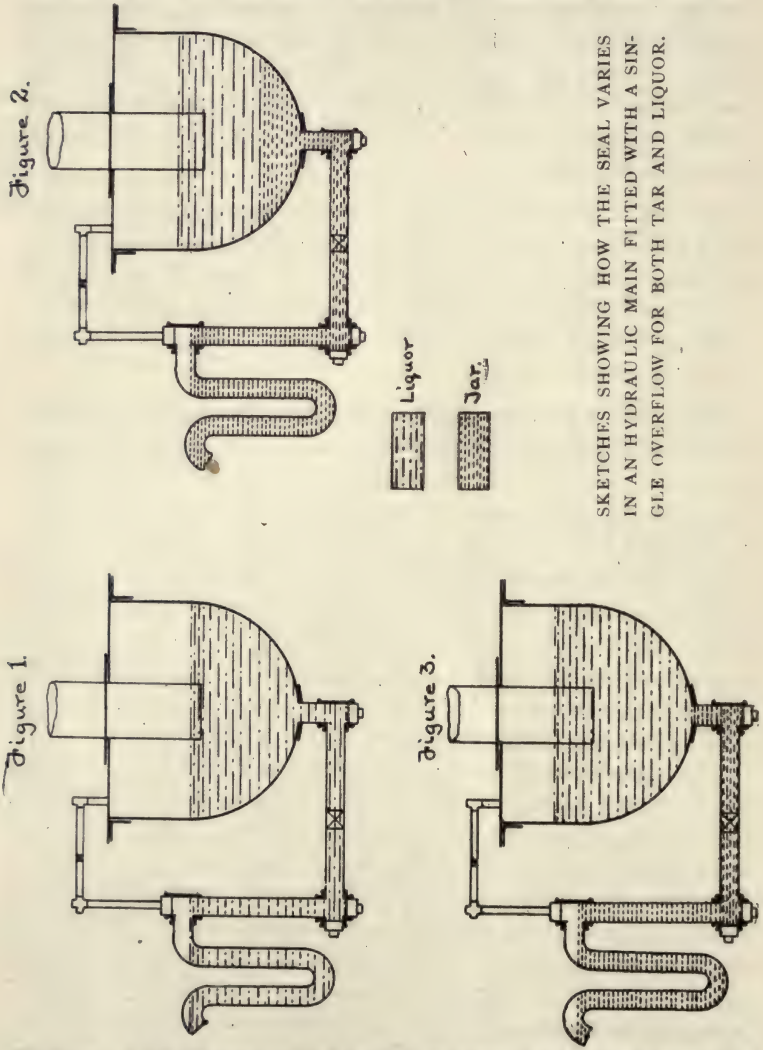
Each section of the hydraulic main must also be provided with a gas take-off of suitable size which connects it with the foul main.

The area of surface of the liquor outside of the dip pipes is determined from the following considerations. It is necessary that the dip pipes should remain sealed when the retorts are open and the surface of the liquor in the dip pipes is subjected to atmospheric pressure, even when the pressure in the main is at the highest point it is likely to attain under the conditions existing in any given works. The unsealing of the dip pipes, when the water is at the proper level, can only be brought about by the forcing up into them of a volume of water equal to the area of the liquor in the main outside of the pipes multiplied by the distance from the normal surface of the liquor to the lower edges of the dip pipes, that is, of a volume equal to the surface area of the liquor multiplied by the normal depth of seal. If the depth of seal is taken as 1 inch, and the greatest pressure that is likely to be thrown on the main as 10 inches, it will be necessary to have the area in the main outside of the dip pipes a little more than 10 times as large as the area inside of the pipes, since if it were less than this all the liquor outside the pipes above their lower edges would be forced up into them, and they would thus be unsealed, before the height of liquor in them was sufficient to balance the pressure in the main. The rule may be stated in general terms as being that the area outside the dip pipes must always be at least as many times greater than the area inside the pipes as the quotient obtained by dividing the greatest pressure likely to exist in the main by the normal depth of seal that it is the intention to carry. When the main is so designed there is no danger of gas passing back out of the dip pipes as long as the water is kept at the proper height in the main.

40. Is it possible to have a single automatic overflow to remove both tar and liquor from the hydraulic main and at the same time maintain a liquor seal of constant depth on the dip pipes? Illustrate the reasoning by which you arrive at your answer by a sketch showing a cross section of the main and of such an overflow.

Ans. Owing to the difference between the specific gravities of tar and ammoniacal liquor it is not possible to have a single automatic overflow for the removal of both tar and liquor from the hydraulic main and at the same time maintain a seal of constant depth on the dip pipes. Such an overflow must connect to the bottom of the main, since otherwise some tar will be allowed to stay in the main indefinitely and gradually stiffen up until it can only be removed by scrapers. The accompanying cut shows cross sections of a hydraulic main with a single overflow opening out of the bottom and serves to illustrate the description of its action which follows.

The main being filled with liquor at the start the conditions are as shown in figure No. 1, the liquor in the two legs of the syphon formed by the main and overflow standing at the same level, and the dip pipes being under the proper seal. But when the main is in operation tar soon accumulates and settles to the bottom, and then nothing but tar can enter the overflow and pass over to its outside leg, as shown on figure No. 2. In this outside leg there is then a column of tar only, while the balancing column in the other leg is composed partly of tar and partly of liquor. The liquor being lighter than the tar, this column of tar and liquor cannot support a column of tar of equal height, and before the tar in the outside leg of the syphon can rise to the level of the overflow and run off, the liquor in the main must rise above this level by an amount which depends upon the length of the outside leg and the proportion of the height of the inside leg which is occupied by the liquor. The seal on the dip pipes will thus be made greater than it should be, as shown on figure No. 2.



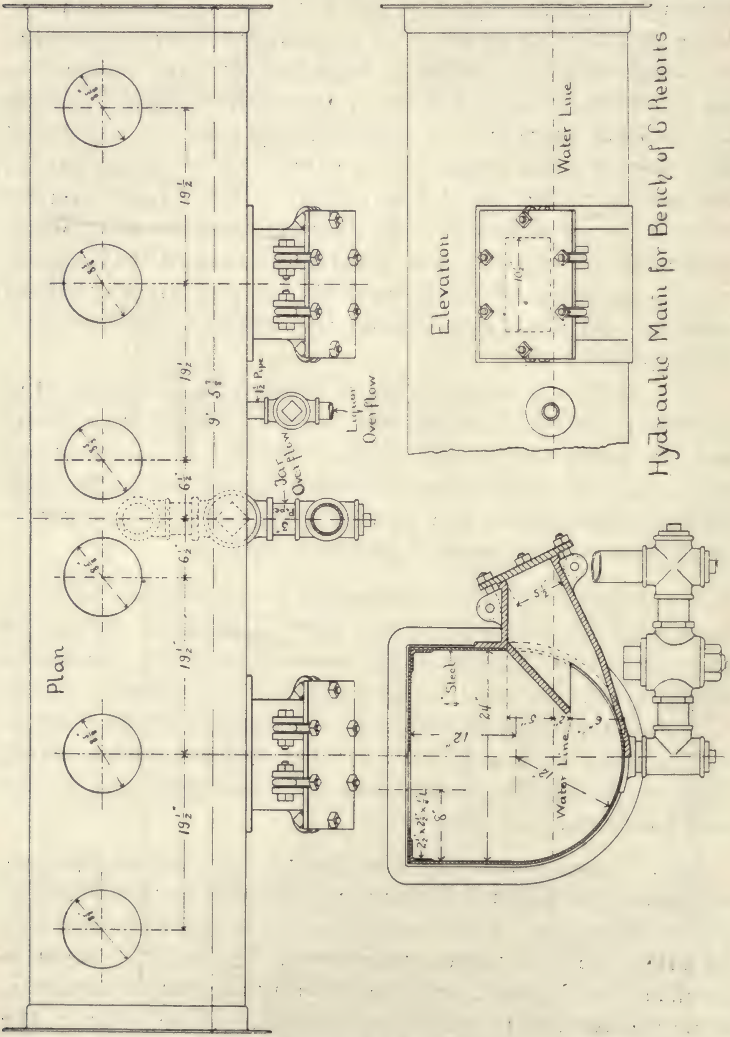
SKETCHES SHOWING HOW THE SEAL VARIES IN AN HYDRAULIC MAIN FITTED WITH A SINGLE OVERFLOW FOR BOTH TAR AND LIQUOR.

Since as long as there is any tar in the main there will be nothing but tar in the outer leg of the overflow and nothing but tar will run off from the main, all the liquor that is formed accumulates, until finally as the tar runs off, the main contains, as shown in figure No. 3, nothing but liquor standing at a level which is sufficiently high to more than balance the tar in the outer leg and drive it out of the overflow. When this happens there will be liquor on both sides of the syphon, and therefore the heights of the two columns will equalize themselves by the rapid flowing out of the liquor from the main until the level has been brought back to the normal water line, at which it will stand until enough tar accumulates to again cut off the liquor from the overflow and fill the outer leg, causing a repetition of the sequence of events previously described.

It is therefore evident that with such an arrangement of overflow, the water line in the main is continually varying and the depth of the seal on the dip pipes is anything but constant. To secure a seal of constant depth and at the same time remove both tar and liquor automatically it is necessary to adopt an arrangement of double overflows.

41. Give a drawing of one length of hydraulic main to be used with the bench of retorts illustrated in the answer to question No. 37. This drawing should show all the dimensions of the main, and also the arrangements for running off the tar and ammoniacal liquor, and for cleaning the main, while in operation, from any heavy tar that may accumulate in it. State in writing the reasons that determine the choice of the dimensions that you give.

Ans. The accompanying cuts show a plan, section and part elevation of a length of hydraulic main made for the bench of retorts illustrated in the answer to question No. 37, and also details of the liquor and tar overflows. The body of the main is made of $\frac{1}{4}$ in. steel, and the cleaning pockets of cast iron, these pockets being bolted, or riveted, to the body at the proper places. They are made, as shown, with their inner upper edges sealed below the liquor in the main so that the covers can be taken off at any time and the main cleaned without interfering with the operation of the retorts. The bottoms of the pockets come up on a gentle slope from the lowest point of the main, and there is nothing to interfere with getting the heavy tar out very easily when it is necessary. The covers of the pockets are fastened down by swinging bolts, and can be taken off and put back again very quickly and readily.

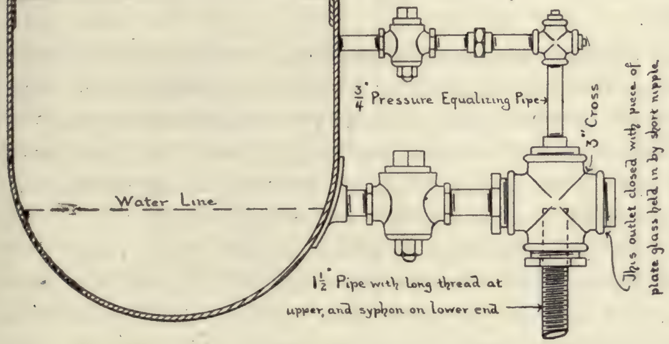

Hydraulic Main for Bench of 6 Retorts

The liquor and tar overflows are made entirely of ordinary pipe and fittings, except that it is well to have the stop-cock on the tar overflow made with the opening in the plug round and the full size of the pipe, which requirement is not fulfilled by the ordinary iron stop-cock. At the same time these overflows are adjustable over a height of 3 in. or 4 in. By setting

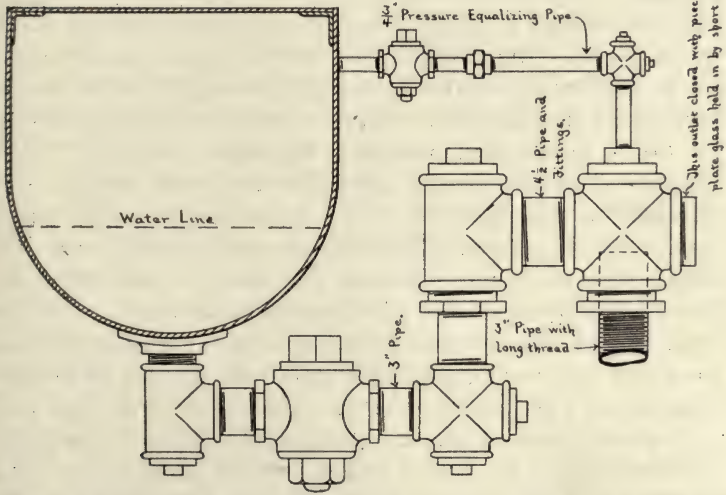
HYDRAULIC MAIN.

DETAILS OF LIQUOR AND TAR OVERFLOW.

Liquor Overflow.


$\frac{3}{4}$" Pressure Equalizing Pipe
3" Cross
This outlet closed with piece of plate glass held in by short nipple.
Water Line
1½" Pipe with long thread at upper, and syphon on lower end

Tar Overflow


$\frac{3}{4}$" Pressure Equalizing Pipe
4½" Pipe and Fittings.
This outlet closed with piece of plate glass held in by short nipple.
Water Line
3" Pipe with long thread
3" Pipe.

a piece of plate glass in the outer horizontal outlet of the cross, into the bottom outlet of which is screwed the adjustable pipe, a means is afforded of observing the depth of the seal at all times.

No gas take-off is shown. A short extension piece bolted on either end of the main, as may be most convenient, is provided for this.

The reasons by which the general dimensions of the main are determined are as follows: The over-all length of each section must be just enough less than the distance between the middle lines of the partition walls of the bench, to allow for the thickness of the gasket required between two sections. The distance between the middle lines of walls being 9 ft. 6 in. in the given case, the main is taken as 9 ft. $5\frac{7}{8}$ in. long. The width is determined by the area of liquor which it is required to have outside the dip pipes, and this depends upon the following considerations. It is necessary that the dip pipes should remain sealed when the retorts are open, and the surface of the liquor in the dip pipes is subjected to atmospheric pressure, even when the pressure in the main is at the highest point it is likely to attain under the conditions existing in any given works. The unsealing of the dip pipes, when the water is at the proper level, can only be brought about by the forcing up into them of a volume of water equal to the area of the liquor in the main outside of the pipes, multiplied by the distance from the normal surface of the liquor to the lower edges of the dip pipes, that is, of a volume equal to the surface area of the liquor multiplied by the normal depth of seal. The depth of seal is usually taken as 1 in., and it is considered that the highest pressure that will have to be provided for will be 8 in. to 9 in. The width required in the given case is therefore found by this calculation. Six dip pipes, having an internal diameter of 7 in. and an external diameter of $8\frac{1}{4}$ in., will have a combined internal area of 291 square inches, and a combined external area of 321 square inches. There being liquor to the depth of 1 in. in the dip pipe under normal conditions, if the area of the main outside of the dip pipes is seven and a half times the total internal area, a pressure of 8.5 in. will be provided for. The area outside of the dip pipes must therefore be at least 7.5 × 291 = 2183 square inches, and the total area of the surface of the liquor should be 2183 + 321 = 2504 square inches. As the length of the main is 9 ft. 6 in. = 114 in., its width at the water line must be $\frac{2504}{114} = 22$ in. This width at the water line is secured by making the main 24 in. wide and of the shape shown. If a greater pressure had to be provided for, it would be necessary to make the main wider. By putting between each two lengths of main a partition extending 4 in. or 5 in. above the normal water line, and thus forming a separate water compartment for each bench, while leaving the gas-way open between the different lengths, the dip pipes on any bench that is idle can be given a heavier seal than those that are working, and thus be made safe against a higher pressure.

42. Give a description, illustrated by sketches, of a full set of retort house firing and cleaning tools. Do not include in your answer tools for repairing, or coal and coke wagons.

Ans.

FURNACE TOOLS.

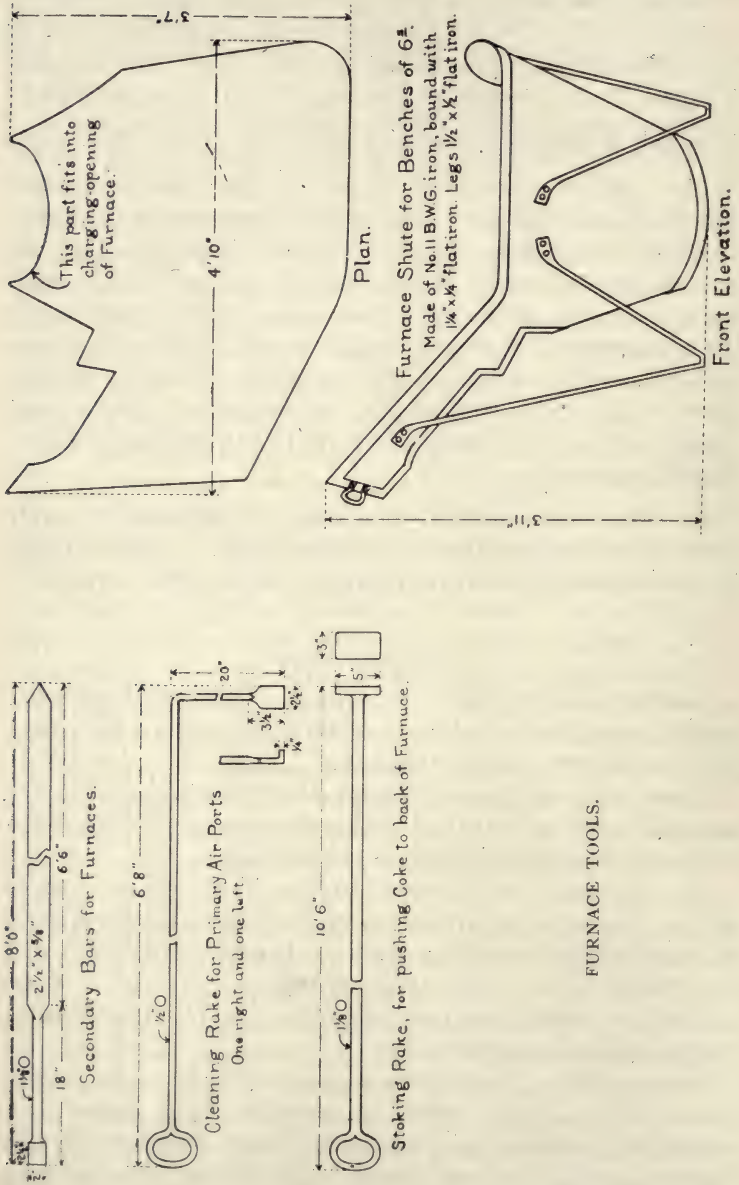
Secondary Bars: Made of 2½-inch x ⅝-inch refined iron, welded to a piece of 1⅛-inch round iron, with a 2-inch head for driving with a sledge hammer.

These bars are driven through the fire above the clinker line, and hold up the fuel while the ashes and clinker are removed from the lower part of the furnace.

Cleaning Rakes for Primary Air Ports into Furnace: Made of ½-inch round iron, with an eye handle and a small rake end at right angles to main portion of handle. One right and one left for the two sides of the furnace.

Used for raking out the ashes that get into the air ports during the cleaning of the fire.

Stoking Rake: Made of a piece of 3-inch x ¾-inch flat iron, 5 inches long, welded in centre at right angles to a round rod, tapering from 1⅛-inches where welded to the flat iron to ⅞-inch at the eye handle, and 10 feet 6 inches long over all.


5'7"
4'10"
This part fits into charging-opening of Furnace.
Plan.
Furnace Shute for Benches of 6s.
Made of No. 11 B.W.G. iron, bound with 1¼" x ¼" flat iron. Legs 1½" x ½" flat iron.
Front Elevation.
3'11"
8'0"
6'6"
2½" x ⅝"
18"
1⅛"O
2¼"
2"
Secondary Bars for Furnaces.
20"
6'8"
3½"
2¼"
¼"
½"O
Cleaning Rake for Primary Air Ports
One right and one left.
3"
5"
10'6"
1⅛"O
Stoking Rake, for pushing Coke to back of Furnace.

FURNACE TOOLS.

Used to push the coke well to the back of the furnace, immediately before and during the stoking draw, to secure an even fuel bed throughout the whole depth of the furnace.

Furnace Shute: Made of No. 11 B. W. G. iron, bent to proper shape, bound with ¼-inch x 1¼-inch flat iron, and provided with legs of ½-inch x 1½-inch flat iron.

It is used to catch the coke as it is drawn from the top and middle retorts on one side of a bench of sixes and cause it to slide into the charging opening of the furnace into which the lower part of the shute fits, the stoking rake being used to push the coke into the back of the furnace from this opening.

RETORT TOOLS.

Drawing Rake: Head made of ¾-inch x 3-inch flat iron, 13 inches long, welded to handle at a point 1½ inches from the end. Handle 1¼-inch round iron, for 18 inches from head, 1-inch round for 8 feet more, and ⅞-inch round for the rest of the 14 feet 6 inches length. Eye on end of handle.

Used for drawing the coke out of retorts.

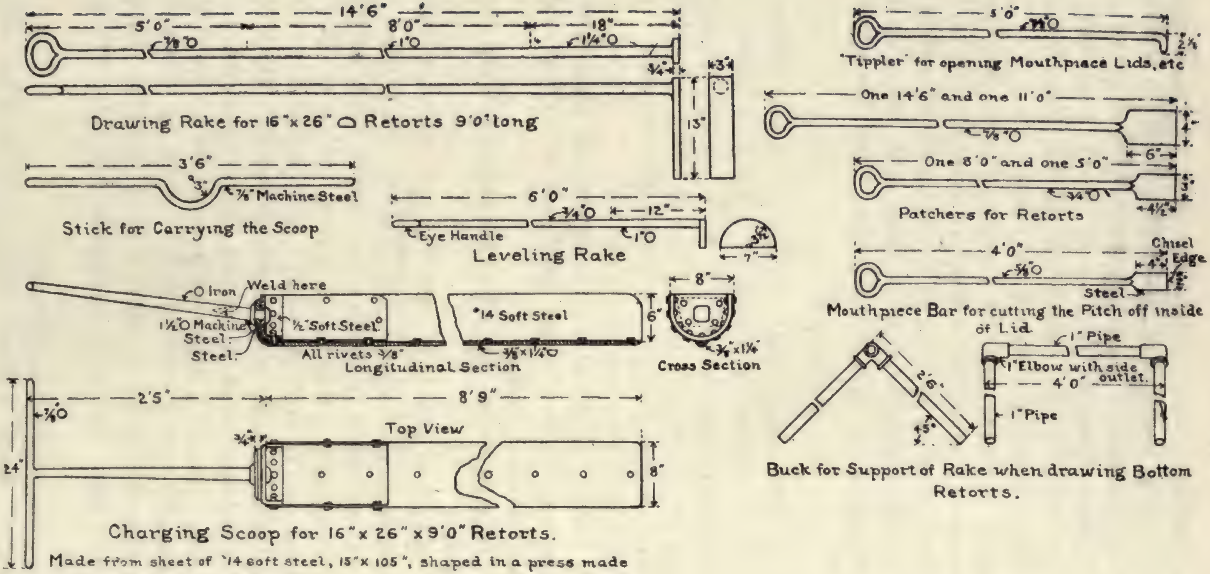
Carrying Stick: Made of ⅞-inch round machine steel, 3 feet 6 inches long over all, and with proper curve in middle to fit the bottom of the scoop.

Used for lifting and carrying front end of scoop when charging the retorts.

Scoops: Made of No. 14 B. W. G. soft steel, cut to size of sheets needed (15 inches x 105 inches), and pressed into shape in a press made of three 6-inch pipes, with necessary screw arrangements. Reinforced for 16 inches at the head with a piece taken from an old scoop. Strip of ⅜-inch x 1¼-inch iron riveted along outside at bottom to stiffen it. Head made of ½-inch soft steel, bent to proper shape on anvil, with a strengthening piece of ¾-inch steel put on around opening for handle. Handle 1½-inch round steel, upset on inside, and welded outside to a piece of round iron of same size tapering to ⅞-inch in 2 feet. Cross-bar of handle ⅞-inch round, and 2 feet over all.

Used for charging coal into retorts.

"*Tippler*": Made of ⅞-inch round iron, with eye handle and short hook on other end tapered down to ⅝-inch at point.



Made from sheet of "14 soft steel, 15"x 105", shaped in a press made of three 6" pipes with clamps, one pipe being forced down on the sheet, bending it as desired. The reinforcement near the handle has been found necessary to prevent breakage.

RETORT TOOLS.

Used on charging floor for slacking off levers, opening lids of mouth-pieces, raising the flaps covering the openings through the floor into cellar, and every other purpose requiring the use of a hook.

Leveling Rake: Made of a piece of ¾-inch x 3½-inch flat iron, cut to a semi-circle of 7 inches in diameter, welded at right angles to a handle 6 feet long, the first 12 inches of which is 1-inch round iron and the rest ¾-inch round, with an eye on end.

Used for leveling back the coal from the mouthpiece into retort after the charge, also for closing the lid and pushing in the lever.

Mouthpiece Bar: Made of ⅝-inch round iron, with eye handle and a chisel end of steel, dressed to an edge and tempered, 4 feet long.

Used to chip off the tar and pitch that accumulate on inside of mouthpiece lids.

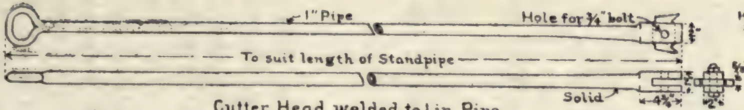
Buck: Made of two 1-inch Ells, with side outlets, and the necessary 1-inch pipe to form four legs and a cross-piece.

Used to support the drawing-rake and raise it above the bottom of the retort when drawing the bottom retorts, thus saving the firemen from much stooping when handling the rake in these retorts.

Patchers: Made, as shown on cut, of different sizes and length of handles. Made to hold fireclay and push it into the required place when patching retorts.

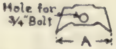
STAND-PIPE TOOLS.

Cutter Head: Forged from 2-inch x 2-inch iron, slotted and drilled, as shown in drawing, for the reception and fastening of cutting tool, and welded to a piece of 1-inch pipe of sufficient length to allow the cutter to reach well into the bend of the stand-pipes from the bottom retorts. Provided with an eye handle parallel to slot in head, so that the direction of the cutter is always known. One of these heads is also welded to a curved handle of ⅝-inch and ¾-inch round iron, similar to the auger handles. The cutting tools for use in these heads are made of ⅝-inch x 2½-inch steel, tempered on

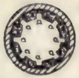


Cutter Head welded to 1 in. Pipe.

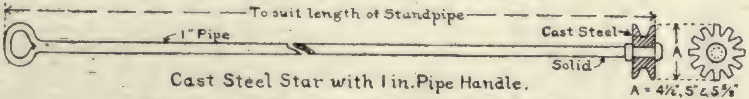
To be used from top of Standpipe. Also one with curved handle, same as Augers, to clean out Mouthpiece end of pipes.



Cutting Tool. 2½" x ⅝" Steel A = 4", 4½", 5" & 5⅝"

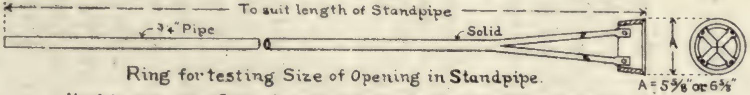


Cross Section of Standpipe showing the Grooves a, a, made by Cutter preparatory to using Star to break Carbon off



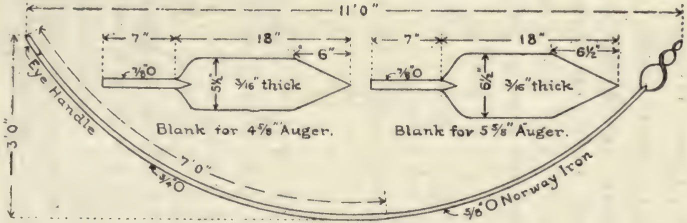
Cast Steel Star with 1 in. Pipe Handle.

Used from top after Cutter. Also one with Auger Handle.



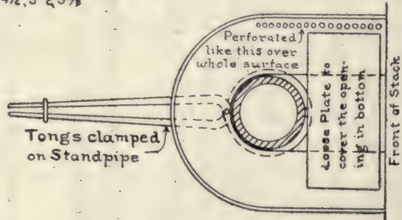
Ring for testing Size of Opening in Standpipe.

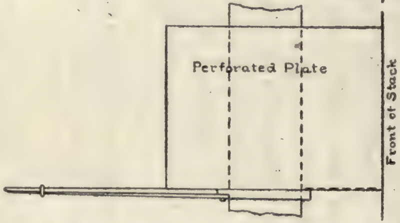
Used from top after Star. No retort charged after scurfing or burning out pipe, until this Ring goes down the pipe easily.



Auger and Auger Blanks.

The same style heads also fitted with pipe handles for use on top.


Perforated like this over whole surface
Loose Plate to cover the opening in bottom
Front of Stack
Tongs clamped on Standpipe



Basket of Perforated Sheet Iron.

Used to soften obstructions completely blocking pipe and too hard to make hole through.

STAND-PIPE TOOLS.

edges of the slope shown on drawing, in sizes increasing by ½-inch from 4 inches up to 5½ inches in extreme width.

This tool is for use in case the carbon in a pipe is too hard to be cut away with other tools. By its use vertical grooves are cut in the carbon, as shown on the cut, almost out to the iron. Then the pipe is fired hard for an hour or so—that is, the flame from wood burnt in the retort is drawn up through the pipe, causing the carbon to crack away from the iron, so that it can be broken off in great lumps by means of the "Star," thus cleaning the pipe quickly, even when badly stopped owing to previous imperfect cleaning. The whole operation can be performed without the excessive jarring and subsequent loosening of joints that is necessary in doing the same work with an auger, with the further advantage that stand-pipes that cannot be cleaned with an auger are amenable to this treatment.

Star: Made from a piece of ½-inch steel plate, cut to a circle of the proper diameter, the teeth then being cut out, as shown, and tempered. It is not necessary to make this double, though it is shown so on the cut. This is fastened to a handle of 1-inch pipe, the length of which is determined by that of the longest stand-pipe. In two sizes for use from the top of pipes; also one provided with an auger handle for use from the charging floor.

This tool is used as the first and only tool in cleaning pipes from hard stoppages that are not bad, and to follow the cutter in the case of pipes in which the carbon has been allowed to grow thick. The largest size is of such a diameter that when it has cut its way down a pipe the ring will follow easily.

Ring: Made of ⅝-inch x 2½-inch steel, drawn to an edge, as shown on drawing. To it are riveted four ⅝-inch rods, welded together at their other ends, the single rod thus formed being welded to a piece of ¾-inch pipe, long enough to allow the ring to drop to the bottom of the longest stand-pipe.

This ring is used merely to detect the presence of any lumps that the "Star" may have slipped by, and is not used to cut away obstructions of any size. It is made from ¼-inch to ⅜-inch less in diameter than the pipes on which it is to be used.

Augers: Made from steel blanks $\frac{3}{16}$-inch thick, and of shape and size shown on the cut. Welded to rods 11 feet long, 7 feet at handle end of which is $\frac{3}{4}$-inch round and the rest $\frac{5}{8}$-inch round iron. These rods have eye handles and are curved, as shown. The auger heads are given at least one full turn, and preferably more. The augers are used to clean the lower portion of the stand-pipe at each draw. Similar heads are fixed on pipe handles for use in cleaning the pipe from above in case of a lamp-black or other soft stoppage.

Basket: It sometimes happens that a pipe is allowed to run so long, or is so handled when the cleaning is begun, that it becomes completely choked up with carbon so hard that it is almost impossible to drive even a pointed bar through it. It is for such cases that this basket is useful. It is made of a piece of perforated iron, cut from a sheet discarded from a rotary coke screen; is open on one side where it abuts against the front wall of the stack, and the bottom has an opening cut far enough back to take in the stand-pipe. A pair of tongs with clamping ring, clutches the stand-pipe and supports the basket at the proper height.

Its use is as follows: In the case described above, the obstruction is located and the point marked on the outside of the pipe. The tongs are then clamped on at the right place, the basket hoisted up and placed upon them, encircling the pipes and touching the front wall of the stack. A wood fire is started in the basket and kept up until the heat softens the obstruction sufficiently to allow a fair-sized opening to be made through it, when it is permitted to die out and the pipe burnt clean in the regular way.

Note.—The dimensions given on all cuts are for tools to be used in 6-inch stand-pipes and retorts 9 feet long. The necessary changes would have to be made in other cases.

43. It is desired to put into service a full depth recuperative retort bench that has been let down. Describe the process up to and including the drawing of the first charge burned off.

Ans. Draw the cold coke from the retorts. Patch the retorts if necessary. Clean out furnace and flues. Close tightly all secondary air-flues and sight holes. Open primary air-flues. Start a small coke fire on the grate. Replace bridge-pipe covers. Gradually increase the fire as the bench heats. Have the clinkering door partly open, that air may enter above the fire and burn the carbon monoxide within the furnace. Gradually increase the fire, and the opening of the main damper, until the combustion chamber and lower retorts are at a dull red heat. Then fill the furnace, close the door, turn water on the water grate, and watch for the appearance of a blue flame at the openings leading from the furnace to the combustion chamber. When this appears, open the secondary air-flues gradually until the flame has shortened, and almost disappeared. The setting will now safely and rapidly come to a working heat. Charge the retorts as soon as they are all at a dull red. Draw the first charge when it is burned out. Begin regular charges when the retort is at a proper working heat. Close the main damper as the heat increases.

44. Describe the putting into operation of a bench of retorts heated by a generator furnace, from the lighting of the fire to the putting in of the first charge, giving the precautions to be taken to prevent any injury to the setting.

Ans. The method to be employed in putting into operation a bench of retorts heated by a generator furnace will depend somewhat upon whether the bench has just been built or reset, or is one that has been previously fired up and let down.

In the case of a new bench, or of one that has just been reset, it is necessary that all the brick work about the bench should be thoroughly dried, by being subjected to a low heat for a long time, before any attempt is made to heat it up to a working point. This drying cannot be hurried without injury to the bench, and at least two weeks should be allowed for it. It is effected by keeping a very low fire on the grate of the furnace, using about two or three bushels of coke at the start and keeping the fire about the same size afterwards. The clinkering door of the furnace should be left wide open, the object being to pass through the bench as much moderately warm air as possible, so as to pick up and carry off the moisture. The primary and secondary air ports should be closed, and also the main dampers. When the fire is first made all the stoppers in the front wall of the setting should be removed, leaving the stopper holes open. An opening the size of one or two bricks header-wise should also have been left in this wall directly under the crown of the arch. As the main dampers are closed the warm air, laden with the moisture picked up in the furnace and the lower part of the setting, escapes through these openings in the front wall, carrying the moisture with it, while if it had to pass all around the retorts and through the take-off flues it would become cool and deposit most of the moisture in these flues before it escaped to the chimney. After the furnace is dried the stoppers can be put in the lower openings and the warm air forced to travel farther along, and so on, until after a week or ten days the main dampers can be opened a little, the large opening under the crown of the arch closed up and the warm and now comparatively dry air drawn through the whole of the setting and the take-off flues, thus drying all portions of the bench.

After the drying out is completed the bench is brought up to working heat in exactly the same manner as a bench that has been let down after a certain amount of service, except that a new bench should be heated up a little more slowly than an old one.

For heating up, a slightly larger fire is built than is used for drying out. Either just before or immediately after this fire is started, any coke left in the retorts from previous working must be drawn, the retort mouthpieces closed, the secondary air ports closed, and all stopper openings and cracks in the brick work carefully plastered up so that no air can get into the bench except through the primary air flues and the clinkering door. The primary air ports are opened slightly, as are also the main dampers. The clinkering door, instead of being left wide open, as in drying out, is only left slightly ajar, since now the object is to have the fire heat the bench and not to have it heat an excess of air passing through the bench. It is necessary to leave the door open a little to admit air above the surface of the fire for the purpose of consuming any carbon monoxide, CO, that may be formed, as soon as it escapes from the fuel, and thus prevent the formation of an explosive mixture of carbon monoxide and air in the upper part of the furnace and in the setting, since such a mixture if allowed to form would probably be ignited later and explode with more or less damage to the bench. It is also necessary that the surface of the fire should never be entirely covered with cold coke, some portion being always left hot and incandescent to ignite the carbon monoxide as soon as it meets the air.

The fire is gradually increased until at the end of from 48 to 96 hours it can no longer be fed through the clinkering door. The plates and water pan of the step grate are now put in, the clinkering door shut, the water started running on the grate, and the primary air ports and main dampers opened wider. The fire is fed through the filling door until the furnace is half full. If cold coke is used, the precaution noted above of never entirely covering the hot surface of the fire must be carefully observed. If hot coke is used, this, of course, obviates any danger of a cold surface to the fire. As soon as the combustion chamber and lower retorts reach a good red heat and the carbon monoxide coming from the furnace is seen to burn at the nostrils when air is admitted to the combustion chamber, the secondary air can be turned on and the bench brought up to heat as rapidly as is necessary, the furnace still being kept about half full of coke, being completely filled only a few hours before the bench is to be put in action.

As soon as the retorts reach a red heat they should be patched and charged with coal, the charge being left in until burnt out. The bridge pipe covers should, of course, be closed before the retorts are charged. When the bench is nearly up to its proper working heat, regular charging can begin, and when this heat is reached the openings of dampers and primary and secondary air ports must be carefully regulated to the proper respective areas.

If necessary an old bench can be put in action within sixty hours after the fire is first started, but it is best to proceed more slowly if possible and spend five or six days in bringing the heat to the working point.

45. After having heated up and put into regular operation a bench of retorts, full depth recuperative setting, how would you proceed to adjust the chimney dampers and primary and secondary air slides in order to secure the greatest fuel economy?

Ans. When a bench of retorts with a full depth recuperative setting has been heated up to the required heat and put into regular operation the proper conditions for economical running are obtained as follows: The chimney dampers are pushed in, until, on opening the charging door of the furnace and throwing into the fire a handful of coal dust, the resulting flame plays lazily back and forth out of the door, being neither drawn steadily in by the draft nor forced out too vigorously by an excess of pressure. If the heat can be maintained with a slight pressure on the furnace great economy of fuel can be attained, but, as a rule, heats cannot be kept up unless the pressure is cut down practically to zero. There should never be a decided "pull" on the furnace except on special occasions, when the heat has to be brought up quickly, without regard to the quantity of fuel used. The dampers set, the heat is brought to the proper point by increasing or decreasing the primary air opening, the secondary air being kept properly proportioned to the amount of carbon monoxide produced by the furnace. The proper amount of secondary air opening is determined by noting the disappearance in the take-off flue, or at any convenient point of observation in the waste gas flues of the recuperators where the heat is not too high, of the blue flame that indicates the escape of unconsumed carbon monoxide from the combustion chamber. If this flame is present the secondary air opening is gradually increased until the flame disappears, waiting a sufficient length of time after each slight increase of opening for the extra air to travel through the bench. When the flame is gone the adjustment is right and the secondary air slides should be clamped. If no flame is present and the adjustment has not been made for some time, the secondary air openings are decreased until the flame appears, and then the adjustment is made as above. As the quantity of carbon monoxide produced varies with the condition of the fire as to the amount of ashes, depth of fuel-bed, etc., the secondary air supply cannot be kept exactly right for every hour of the day, and this being so, enough is supplied to consume the average maximum production of carbon monoxide, since the loss of heat due to the small excess of secondary air, present when less carbon monoxide is made, is smaller than would be suffered by allowing an equal quantity of carbon monoxide to escape unconsumed, the loss of sensible heat being practically equal in both cases, while with the unconsumed carbon monoxide there is the additional loss of its heat-producing power. If there is sufficient recuperating surface in the bench, the appearance of any heat above a dark red in the recuperators below the point of entrance of the secondary air is an almost certain indication of an insufficient secondary air supply, even though no flame can be seen, the flame not being very marked in a highly heated space.

After this adjustment of the damper and air slides is made, they are fastened so securely that it is impossible for them to be moved unintentionally.

Recuperative benches will not give the best results, nor the highest heats, unless the adjustments spoken of above are properly made, and the making of them should not be left entirely to the average retort house fireman, nor even to the average foreman, until he is taught enough of the principles of generator firing to have some insight into what he is trying to do. Even then regular investigation by the superintendent of the conditions of damper opening and air supply will tend to keep down the percentage of fuel used.

If the works is equipped with a gas analysis apparatus and an employee who is enough of a chemist to be able to obtain accurate results with this apparatus, the supply of secondary air can be regulated by means of analyses of the waste gases more closely than by the method described above. The latter will, however, give results that will be as good as, and probably even better than, those obtained from analyses that are improperly or carelessly made.

46. Describe the operation of a bench of coal gas retorts heated by a recuperative furnace, either half-depth or full-depth, including the care and operation of the furnace, standpipes and hydraulic main.

Ans. The first point to be noted in operating a recuperative bench is the regulation of the draft. The chimney dampers should be pushed in until on opening the charging door of the furnace and throwing into the fire a handful of coal dust, the resulting flame plays lazily back and forth out of the door, neither being drawn steadily in by the draft, nor burning up vigorously. The dampers set, the heat is regulated by increasing or decreasing the primary air opening, the secondary air being kept properly proportioned to the amount of carbon monoxide produced by the furnace. The chimney dampers will need re-adjustment, if the quantity of fuel consumed varies materially.

The proper amount of secondary air opening is determined by noting the disappearance in the take-off flue, or at any convenient point of observation in the waste gas flues of the recuperators, where the heat is not too high, of the blue flame that indicates the escape of unconsumed carbon monoxide from the combustion chamber. If this flame is present, the secondary air opening is gradually increased until the flame disappears, waiting a sufficient length of time after each slight increase of opening for the additional air to travel through the bench. When the flame is gone, the adjustment is right and the secondary air slides should be clamped. If no flame is present and the adjustment has not been made for some time, the secondary air openings are decreased until the flame appears, and then the adjustment is made as above. The quantity of carbon monoxide produced varies with the condition of the fire as to the amount of ashes, depth of fuel-bed, etc., so the secondary air supply cannot be kept exactly right for every hour of the day, and this being so, enough is supplied to consume the average maximum production of carbon monoxide, since the loss of heat due to the small excess of secondary air present when less carbon monoxide is made, is smaller than would be suffered by allowing an equal quantity of carbon monoxide to escape unconsumed ; the loss of sensible heat being practically equal in both cases, while with the unconsumed carbon monoxide there is the additional loss of its heat-producing power. After this adjustment of the damper and air slides is made, they should be fastened so securely that it is impossible for them to be moved unintentionally.

It is necessary for the proper working of a generator furnace that the fuel-bed be kept deep and the depth be uniform throughout the furnace.

In cleaning the fire, there should be no work done from the top of the furnace, allowing a rush of cold air through the bench. All the work should be done through the cleaning door with a good bed of fuel left in the furnace to heat the excess of inflowing air. Secondary bars, resting on supports provided for the purpose, are driven in above the clinker line to hold up the fire; the grate bars are drawn, dropping the ashes into the pan; any hard clinker on the walls is cut away with chisel bars, the grate bars are replaced and the secondary bars withdrawn, thus letting the fire down upon the grate again. After taking out the ashes dropped into the pan during the cleaning of the fire, the dirt that has worked into the primary air openings should be raked out.

Every six weeks, or two months, the recuperator flues should be cleaned of the deposit of flue dust, as this interferes with the free transmission of heat through the walls to the secondary air. The primary air flues also need regular attention, the bursts of steam caused by the dropping of hot ashes and clinker into the water in the ash pan, when the fire is cleaned, carrying fine dust back into these flues beyond reach from the furnace.

Passing now to the care of the standpipes, these should be kept clean. The portion near the mouth-piece should be thoroughly cleaned each time the retort is drawn, and if choked so that the auger cannot be forced up at this time, should be augered after the charge has been in about an hour, when the obstruction will have been softened. The whole pipe should be cleaned every time the retort is scurfed, so as to allow the passage of a test ring one-quarter of an inch less in diameter than the pipe. The same course should be followed if the pipe stops up from any cause, the retort never being put back into action until a ring as above will pass down the full length of the pipe.

Unless means for removing the tar as it forms are provided it should be run off the hydraulic main at least twice in every twenty-four hours, and more often in case the main is small, to avoid any possibility of the dip pipes being sealed in tar. In case the tar becomes too thick to run through the take-off, it must be cleaned out through the cleaning holes with which the main should be provided. While running off the tar, care must be taken to maintain the seal on the dip pipes. Ordinarily the seal is maintained by the liquor condensed from the gas, and a suitable overflow must be provided at the right height to carry off this liquor.

47. It is desired to "let down" a bench of coal gas retorts heated by a recuperative furnace. What is to be done in order that the bench may, with safety, be cooled down and kept idle until the increasing demand for gas, or other reasons, shall make it important to again fire it up? No repairs are to be made to the bench.

Ans. In letting down a bench of retorts with full depth recuperative setting, the last charge should be made as large as the retorts will hold. That is, if the charges are of four hours duration and the bench is to be let down at 7 o'clock, the charges from 3 o'clock on should be made to almost fill the retorts. The coke from these charges must not be drawn until the bench is cold. The furnace should be left half full of coke. When the last charge is put in, the primary air-slides should be shut down to within ½ inch of being closed, secondary air shut off entirely and the dampers closed until there is just sufficient opening left to maintain a slight draft in the furnace. Two or three hours after the last charge is put in, the primary air ports should be closed entirely, all cracks around the brick work plastered up, so as to prevent the entrance of any air into the setting, the opening around the furnace charging door filled with coke dust or ashes to prevent any influx of air at that point, and the dampers practically closed, leaving them just cracked, so as to take off what little gas is still being generated in the furnace, but not open enough to cause any draft through the bench. After the gas is all driven out of the coal in the retorts, the bridge pipe covers should be raised, so that in case there is any leakage of gas up the dip pipes through excess of pressure in the hydraulic main, it will escape through the open bridge pipes, instead of working down into the retorts and forming an explosive mixture which might be fired and damage the bench. After all these precautions have been taken, the bench must be allowed to cool down thoroughly, which it will do very slowly, before anything about it is opened for examination or for cleaning the furnace. If handled in this way, the cooling of the setting will be so gradual as not to cause any avoidable injury to retorts or blocks.

48. Give your theory of the causes of stoppages in the stand-pipes of coal gas retorts and the means you would employ to prevent them.

Ans. The causes commonly accepted as leading to excessive trouble from stoppages in the stand-pipes of coal gas retorts are :

1st. The subjection of the gas in the retort and stand-pipe to excessive pressure owing to the dip-pipes being sealed in tar, to the hydraulic main being choked with pitch, to the stand-pipes being too small originally or having been allowed to become partially filled up, or to the existence of obstructions in other parts of the apparatus which cause pressure to be thrown on the hydraulic main and consequently on the stand-pipe and retort.

2d. Irregularity in working owing to irregularity either in the heat of the retorts or in the weight of coal put into the retorts at successive charges.

3d. High heats and large yield of gas per pound of coal.

Most of these causes are, so to speak, indirect causes leading up to and rendering inevitable the final action in the stand-pipe itself, which, of course, is the direct cause of any stoppage. It seems probable that irregularity in working, which is more apt to occur when high heats are employed to secure the complete carbonization of the coal, since with low heats and yields it is easier to keep the working regular, is the most fruitful of these indirect causes in producing stoppages in stand-pipes. In spite of large stand-pipes, a liquor seal, or even no seal at all, a free flow of gas produced by an exhauster taking all pressure off the hydraulic main, and comparatively low heats, stopped stand-pipes will be frequent and troublesome unless the heats are kept even and the same weight of coal can be, and is, properly carbonized on each charge. On the other hand, high heats and large yields may be the rule, and other bad conditions may exist, but if the working is regular, stopped stand-pipes will be few in number. When we consider the conditions existing in the stand-pipe itself that tend to produce stoppages, the reasons for this great influence of regularity in working, or the reverse, are apparent.

With the retort heats, now usually employed, there is probably always a small amount of free carbon in the form of light particles of soot in the gas as it passes from the retort. A certain amount of condensation is also continually going on in the stand-pipe, the liquid products of which run down the inner side of the pipe walls, becoming thicker and thicker as the lighter constituents are distilled out by the greater heat encountered in the lower portions of the pipe. Under these conditions a stoppage may occur in any one of three different ways.

The amount of solid matter may be large enough to cause a dry soot stoppage, which, however, is easily removed, or there may be a complete though comparatively gradual stopping of the pipe through the conversion of the condensation into successive layers of pitch until the pipe is completely closed, or finally the distillation of the condensation may only proceed to the thick tar stage, and this tar catching the soot forms a thick, pasty, gluey mass, which completely closes the pipe. It is this last form of stoppage that is principally produced by irregular heats and hit-or-miss charging. When the heats are down or too large a charge is put in, the stand-pipe is well coated with thick tar, and if on the next charge too liberal an allowance is made for the previous error a quantity of soot is produced, to be caught by this tar, with a stoppage as the result.

If this theory as to the cause of stoppages in stand-pipes is true, as seems probable, it will be seen that even under the conditions of even heats and charging of the retorts, properly designed stand-pipes and hydraulic main and the maintenance of a uniform low pressure or even a slight vacuum on the main, there is always a tendency for the stand-pipe to stop, owing to the absorption of the solid particles, always present in the gas, by the liquids condensed from the gas during the cooling that must inevitably occur in its passage up the stand-pipe and the coking of the mixture so produced as its volatile constituents are driven off by the heat of the gas passing through the stand-pipe.

The remedies suggested to overcome this tendency of the stand-pipe to become stopped may be classed under two heads: 1st, those designed to strain the solid particles out of the gas before it leaves the mouthpiece by the use of gratings, screens of wire cloth, or similar appliances, through the openings in which the gas has to pass before it reaches the stand-pipe, and 2d, those designed to alter the temperature conditions that exist in the stand-pipe. The second class may be subdivided into appliances having for their object the reduction of the amount of condensation in the stand-pipe by preventing, as far as possible, loss of heat by radiation, and those having for their object the securing of a more rapid condensation through cooling the stand-pipes by artificial means, as well as by cutting off, as far as is possible, the heat radiated from the benches. The remedies belonging to this last subdivision have proved the most successful, the effect of keeping the pipes hot being in almost every case merely the transfer of the trouble to the bridge-pipe, dip-pipe or hydraulic main. In general, they depend on the use of a small jet, or jets of water either playing on the outside of the stand-pipe, which is kept cool by the evaporation taking place, and thus cools the gas more rapidly, or trickling down the inside, in which case the gas is cooled directly. Stand-pipes corrugated so as to increase the amount of radiation by increasing the surface, and stand-pipes made very thin, have also been employed.

The reason for the success of these cooling arrangements in preventing stoppages is not clearly understood. In a paper, "Stoppages in Ascension Pipes," read before the American Gas Light Association in 1880 (see Proceedings, Vol. IV, pages 232 to 250), Mr. Theobald Forstall stated his belief that they were successful only because they produced "a simultaneous and indirect cooling of the mouthpiece which was in itself sufficient to accomplish the result." He says, "it appears to me probable that, under certain conditions of coal and high retort heats, a series of hydrocarbon vapors may be produced in the early stages of the distillation which solidify upon contact with the relatively cool surface of the ascension pipes; and, further, that in order to effectually prevent stoppages from this cause, these vapors must be completely intercepted in the mouthpiece itself. This could be effected by cooling the mouthpiece to that point only which will determine the condensation within it, in a liquid form, of all vapors which solidify on their passage to the hydraulic main; but, at the same time, leaving the ascension pipes to retain their normal heat, so as to allow the greater portion of the tar vapor to pass over to the hydraulic main. Perforated diaphragms or gratings in the mouthpiece would assist in this condensing process, as well as entrap the soot deposit."

Another explanation of the beneficial effect of cooling the stand-pipes is given by Mr. N. H. Humphrys in an article, "Stoppages in Ascension Pipes" (published in the Journal of Gas Lighting, Vol. LXIX, page 403, and reprinted in the American Gas Light Journal, Vol. LXVI, page 684) from which the following quotation is taken: "* * * it would appear that a certain quantity of finely divided solid matter is carried forward from the retort to the ascension pipe. Being partly softened by the heat, or charged with tarry matter, it would soon form a ring round the lower part of the ascension. Condensed matters from the upper part, slowly trickling down, and being rendered more and more viscid by the vaporizing of their lighter constituents as they successively reach warmer and warmer surfaces find a lodgment here, and are retained and baked into hard coke or graphite. But supposing the condensation is increased by additional cooling influences. The deposit trickling down the interior of the ascension pipe will then not only be more abundant, but more liquid—sufficiently so not only to reach the mouthpiece itself, but also to carry the solid particles with it. I take it that these choke-preventing devices act by conveying down into the mouthpiece the matters that, under other circumstances, would form chokes. Apparatus for effecting this result has the practical advantage of being cheap, easily applied to existing apparatus without stopping the make of gas, and as easily removed if found to be unsuitable." He also states that the same effect of extra condensation can be produced in many instances by lengthening the stand-pipes. Both of these papers should be read by the student.

In conclusion it may be safely stated that with 6-inch or 7-inch stand-pipes, which are kept clean and free from deposited carbon, even heats and regular charging, a liquor seal of not more than one inch, and an absence of pressure on the hydraulic main, trouble from stopped stand-pipes can be kept at a minimum and at the same time high heats be employed to secure a large yield per pound, while, if trouble does come, it can be diminished by cooling the mouthpiece and lower portion of the stand-pipe. All of which is subject to the condition that, like naphthalene, stopped stand-pipes at times do not seem to be amenable to any treatment, owing probably to the existence at different times of variations in the conditions which are not discovered nor understood.

49. Describe the cleaning of a badly stopped stand-pipe.

Ans. A stand-pipe may be stopped with soft pitch, with hard pitch, with lamp black or with a mixture of soft pitch and lamp black. If the stoppage is so situated that it cannot be cleaned from the floor with the mouthpiece tools the work must be done from the top of the hydraulic main, the top cap of the stand-pipe being removed for the purpose.

The first step is to make and maintain as large an opening as possible through the obstruction. If the stoppage is bad it may be impossible at first to do more than put through an inch pipe or iron rod, and it may be even necessary to heat this rod before it can be forced through the obstruction. Having secured an opening a wood fire should be made in the front of the retort and the mouthpiece lid partly closed, so that the draft through the opening in the stand-pipe will draw the flame and hot air from this fire up through the stand-pipe. This will, after a length of time depending upon the nature and character of the stoppage, burn off the soft pitch and either soften the hard pitch or make it brittle so that it can be cut away by the cutting tools. Should the opening close up after it is first made, as it may if the stoppage is soft pitch, the pipe or rod should be at once employed and another opening made. When a permanent opening through the stoppage is secured the cleaning of the pipe is merely a question of time, and is gradually achieved by increasing the size of the opening so that fresh surfaces of the pitch can be acted upon by the heat.

Should it be impossible to force an opening through the stoppage, even with a red-hot bar or pipe, an iron basket kept for the purpose can be clamped to the standpipe at the point where the stoppage is located and the obstruction exposed to the heat of a fire built in this basket until it is possible to make an opening through it. Then a fire should be made in the retort and the operation as outlined above proceeded with.

After a permanent opening is secured frequent attempts should be made to cut away the obstruction with the proper tools, as much being cut away each time as will come without too much jarring of the stand-pipe. The pipe should not be considered clean until the pitch and carbon have been so far removed as to permit a ring $\frac{1}{4}$ in. less in diameter than the pipe to pass freely down the whole length of the pipe.

Ordinarily an opening can be made without resorting to the use of a basket and outside fire, and there are very few stoppages that cannot be softened by the use of the basket and cleaned out with the stand-pipe in place. If the stand-pipe has been allowed to become very heavily coated with carbon, as a result of previous incomplete cleanings, it may be so completely stopped with this carbon, which requires intense heat for its removal, as to make it impossible to clean it in place. In this case it must be taken down and cleaned over a fire in the yard. However, if care is taken never to put a retort in action after a stoppage until the pipe is thoroughly clean, as determined by the test mentioned above, there should be no stoppages which cannot be removed with the pipe in place.

The stand-pipe should also be cleaned each time the retort is scurfed, for the hot air passing up the stand-pipe during this operation will loosen the pitch and carbon so that it can be easily removed by the cutting tools. The same test of cleanness should be applied in this case as when a stoppage has occurred and been removed.

50. What are the causes of the deposition of carbon upon the interior of coal gas retorts?

Ans. The carbon deposits upon the interior surfaces of coal gas retorts are caused by the carbon set free by the breaking down, under exposure to heat, of the heavier hydrocarbon vapors and gases evolved from the coal into hydrogen and hydrocarbons containing less carbon and more hydrogen. The extent to which the breaking down and the consequent setting free of carbon takes place depends upon the conditions existing in the retort. Since it is impossible to produce a fixed gas by the destructive distillation of coal or oil without setting free some carbon, a certain amount of deposit in the retort is unavoidable in coal gas manufacture. This unavoidable amount may be, however, and often is, largely increased by an over-decomposition of the gases and vapors due to various causes.

Chief among these are high heats and unduly prolonged contact between the gas and the walls of the retorts. The higher the temperature to which hydrocarbons are exposed and the longer the exposure continues or the greater the amount of surface over which they pass, the more complete is their breaking down, until ultimately they are entirely decomposed into hydrogen and solid carbon. Other considerations render it economical to employ high heats for the distillation of coal in spite of the increased carbon deposits formed, and therefore it is important that care should be taken to make the extent of the exposure of the gas to contact with the walls of the retort as small as possible.

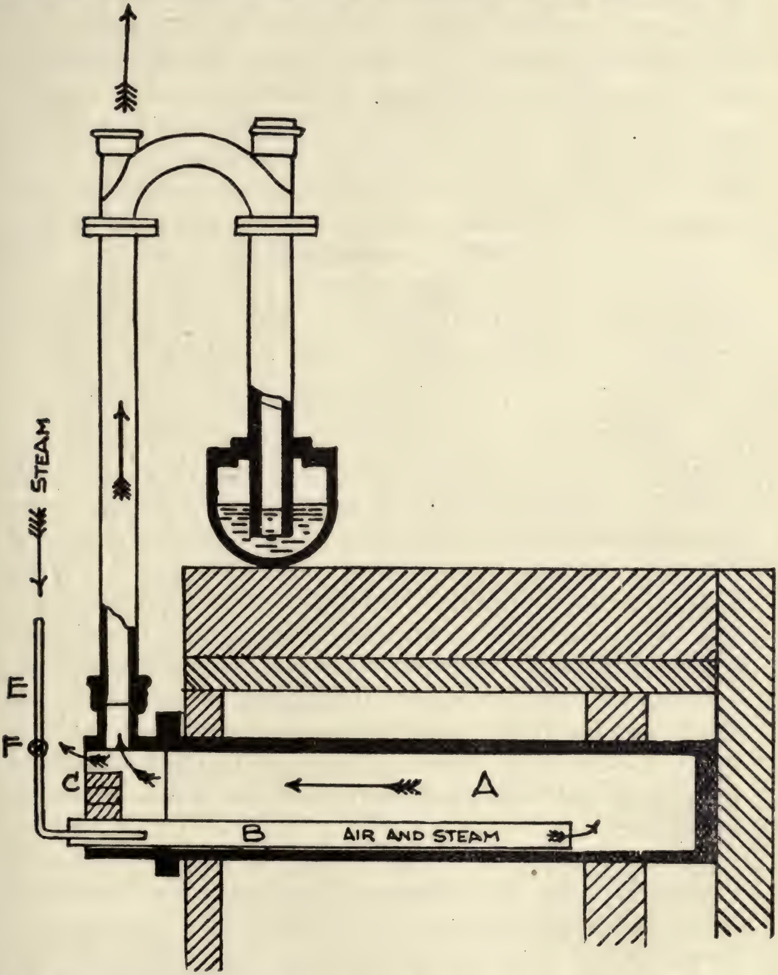
To accomplish this object the free space in the retort, that is, the space not occupied by the charge, should be made small and the gas should be allowed to flow from the retort in a steady stream without pulsations. The statement is very often made that throwing a pressure on the retort retards the flow of gas from it and therefore increases the amount of carbon deposited. If the pressure were a steady one and within the limits ordinarily met with in gas works, it would have very little effect upon the speed with which the gas leaves the retort. However, gas escaping through dip-pipes sealed in liquor does not pass out under a steady pressure, since it must accumulate pressure before it can escape by forcing the liquor out of the dip-pipe, and as soon as this pressure is relieved the seal is re-established to be again overcome, the result being a constant fluctuation of the pressure and a back-and-forth pulsation of the whole volume of gas in the retort as it travels along. It can be readily understood that any given volume of gas will be subject to more contact with the walls of the retort if it moves alternately backwards and forwards, even though the forward motion is relatively as rapid as it would be if it were steady, than it will be if the motion is continuous in one direction only. The greater the initial pressure to be overcome, the more violent are the fluctuations and consequently the longer are the pulsations, and it is probable that it is in this way that pressure increases the deposition of carbon. A reduction in the amount of seal on the dip-pipes also reduces the extent of the pulsation, and therefore reduces the amount of carbon deposited.

The principal causes of the deposition of carbon upon the interior of coal gas retorts seem thus to be a high temperature of the walls of the retorts and excessive friction of the gas against those walls by reason of the pulsating motion by which it escapes through the sealed dip-pipe. The high temperature is necessary for economical working, but the flow of gas out of the retort should be made as steady as possible by reducing the depth of seal to the lowest point possible.

51. State why it is important to remove the carbon deposited upon the interior of retorts, and describe the method by which it is removed, giving the precautions to be observed to avoid injuring the retort.

Ans. It is important to remove deposited carbon from the interior of a retort, for if allowed to accumulate it reduces the capacity of the retort, and increases the resistance to the passage of the heat to the coal being distilled.

Carbon is ordinarily removed from retorts by so-called "scurfing" with chisel bars. In order that the chisel bars may be used without damage to the retorts, it is necessary that the carbon be first loosened from the sides of the retorts. This may be accomplished by causing a current of air to pass over the carbon, which partly burns it off, and causes it to lose its hold on the surface of the retorts. The best method of introducing the air is the invention of Mr. G. W. Edge, at one time connected with the Jersey City Gas Works. The operation of Mr. Edge's plan is shown on the accompanying cut.



A is the retort to be scurfed. B is a pipe or tile laid in the bottom of the retort and extending to within two or three feet of the rear end. This may be three or four inches in diameter. E is a steam pipe controlled by the valve F and terminating in a nozzle G. Steam being turned on at F, and blowing into the pipe B at G, draws with it a large volume of air through the front end of B. This air is blown against the carbon in the back end of the retort A, and, coming forward highly heated, passes over and partially consumes the carbon in the retort, loosening the remainder, so that it may be safely removed with a chisel bar carefully used. Compressed air may be used to induce the draft instead of steam.

The air may be introduced without the use of steam, the mouth of the retort being closed by a tile wall C, surrounding the pipe or tile B, the open stand-pipe D making the draft.

52. How would you make a working test of the proportion of volatile matter and coke in any sample of coal?

Ans. To make a working test of the amount of volatile matter in any given sample of coal, weigh out enough of the coal to make an average charge for, say, two retorts, and put it into two adjacent retorts, care being taken to secure a fair sample of the coal to be tested and to select retorts fully up to the normal heat. Draw the retorts containing the weighed charge at the regular time, and if the coke is well burned out, catch it in a barrow or buggy (the floor in front of the retorts should be swept clean, and all the coke that falls on the floor during the draw be picked up and put in the barrow) and weigh it at once while hot, and before any water is used to quench it.

The difference between the original weight of the coal and the weight of the coke is the weight of the volatile matter driven off during carbonization, and this multiplied by 100 and divided by the weight of the coal, gives the percentage of the volatile matter in the coal. Thus, if 600 pounds is taken and the coke weighs 402 pounds, $600-402 = 198$ pounds is the weight of the volatile matter, and $\frac{198 \times 100}{600} = 33$ is the percentage of volatile matter in the coal. In the same way the percentage of coke can be figured. In the case assumed above it is $\frac{402 \times 100}{600} = 67\%$.

If the coal is wet, it should be allowed to dry before being weighed for the test, and if, when the retorts are opened, it is found that the gas has not been thoroughly expelled from the charge, the coke should not be weighed, but another lot of coal should be weighed out and another test made.

Tests of this kind are valuable as giving, to a certain extent, a check on the quality of the coal supplied, and should be made either on each shipment, or, if this is not convenient, on every third or fourth shipment received.

53. In what size pieces is it advisable to have gas coal when it is charged into the retorts in order to secure the best possible results as to yield of gas per pound of coal and per retort? Give the reasons for your answer.

Ans. The rule generally given for the size of the pieces to which gas coal should be reduced before being charged into the retorts is that the lumps should be broken to the size of a man's fist. But since the size of one man's fist is not necessarily that of another man's fist, it is better to state the rule as being that the lumps should be broken to pieces, none of which measure more than 3 in. along any edge.

The main reason for the attainment of better results when the large lumps of coal are broken to smaller pieces, is that the heat does not readily penetrate to the interior of large lumps and that consequently the gas is never entirely driven off from the coal in the centre of such lumps. Hence, the yield of gas per pound of coal is reduced unless the weight of the charge is kept below the weight that could be properly carbonized if the coal were in small pieces. The same is true of very fine dusty coal, which forms a compact mass in the retort, into the centre of which the heat does not readily penetrate, and the best results as to yield of gas per pound of coal and per retort per 24 hours can only be obtained from coal in the shape of small lumps not larger than 3 in. cubes.

The small pieces of nearly uniform size possess the further advantage of making it possible to have the weight of the charge uniform throughout the whole length of the retort. This uniformity cannot be secured when large lumps and fine coal are used together, or when only large lumps of irregular shape are used. The custom that obtains in some gas works of charging the top retorts of a bench by throwing into them the lumps that are too large to be handled in the charging scoop should be condemned for these reasons, and care should be taken to have all the lumps reduced to pieces of the size specified above.

According to some experiments made by a French gas engineer, not only is a larger yield per pound obtained when the coal is in lumps of this size, but the gas is also of slightly better quality than when smaller lumps are used. In making these experiments lumps of the size being experimented with were used in each case, without any admixture of dust, and the smaller lumps were made by breaking larger ones, so that the coal was exactly the same in every respect except that of size.

54. In making coal gas what influence has the relation between the volume of the charge of coal and the volume of the retort upon the quality of the gas produced from the coal.

Ans. The relation between the volume of the charge of coal and the volume of the retort, or as it is sometimes expressed, the relation between the area of the cross section of the charge and that of the cross section of the retort, has a very decided influence upon the quality of the gas produced and also upon the amount of trouble experienced from stoppages in the stand-pipes and thickening of the tar in the hydraulic main. The quality of the gas is at its best, other things being equal, and the least trouble is experienced, when the volume of the charge is such as to almost completely fill the retort.

The reason for this can readily be seen when the effects produced upon the coal and gas by the exposure to heat to which they are subjected are considered. When the charge is first put into the retort, the temperature of the coal, and of the portion of the surface of the retort covered by the coal, is low and the products of distillation are hydrocarbons of high boiling points, that exist as vapors at the temperature in the retort, but condense to liquids when cooled to atmospheric temperatures. As the charge becomes heated, however, hydrocarbons of lower boiling points are given off which will remain in the state of gas or vapor at atmospheric temperatures. The interior surface of the retort has by this time again reached its original high temperature, and as the hydrocarbons evolved from the coal pass, on their way to the stand-pipe, through the space left above the charge, they are exposed both to contact with this hot surface and to the heat radiated from it. The effect of this exposure is to break up the more complex hydrocarbons and form hydrogen, simpler hydrocarbons, and free carbon, and, given a temperature sufficiently high and an exposure of sufficient length, the final result would be the formation of a gas consisting of hydrogen and marsh gas with no higher hydrocarbons, and the setting free of a large amount of carbon. Such a gas would be non-luminous, so that, although a certain amount of this breaking up of the higher hydrocarbons after they are evolved from the coal is required to produce a permanent gas, especially at the beginning of the distillation, it is important that the operation should not be carried too far.

The length of time during which the gas will be exposed to this heat depends upon the velocity with which it travels, and this velocity in turn depends upon the area of the part of the cross section of the retort that is not taken up by the charge and upon the rate at which gas is being made. An increase in the volume of the charge for a given size of retort will therefore increase the velocity with which the gas passes to the stand-pipes, first, by reducing the area of the space through which it passes, and, second, by increasing the rate at which the gas is made, the combined result being that the gas remains exposed to the action of the heated surface of the retort for a much shorter time and is therefore much less affected by this exposure.

It is true that, although the gas is less exposed to radiant heat when the space is small and the velocity great, a larger percentage of it is brought into actual contact with the surface of the retort, owing to the increase in the ratio between the perimeter and the area of a polygon that occurs when the area is reduced, and that it is also exposed to contact with a greater amount of heated surface as it escapes from the interior of the charge. But experience shows that the combined effect of the radiant heat and the contact with the heated surface in the space above the charge is less harmful when the space is small, and contact with the heated portion of the charge does not have as much effect as contact with the surface of the retort, since during the period in which the greatest amount of gas is given off, the temperature of the charge is much lower than that of the retort walls, as, during the first two hours, the temperature of the charge does not exceed 1200° F., while that of the interior surface of the roof of the retort is, in recuperative benches, about 2000°.

It is therefore important that the size of the retort should be so chosen that the charge which can be carbonized in the desired length of time with the heat to be carried, will fill the retort as full as it is possible to have it and still leave room for the operation of the drawing and charging tools.

55. What are the chief commercial products obtained by the gas manufacturer from the distillation, in retorts, of 2,000 pounds of average Pittsburg or Youghiogheny coal? What amount of each is produced and what effect has the temperature of the retorts upon these amounts?

Ans. The chief commercial products obtained by the gas manufacturer from one net ton (2,000 pounds) of average Pittsburg or Youghiogheny coal distilled in coal gas retorts at a fairly high temperature are,

9,800 cubic feet of gas of 14 to 15 candle power, as determined with a flat flame burner,
1,300 pounds of coke,
12½ gallons of tar,
27 gallons of ammoniacal liquor of from 6 ounces to 8 ounces (3° to 4° Twaddel) strength,
1 pound of retort carbon.

These are average figures, but no two works will agree exactly in the results obtained. The 1,300 pounds of coke would be the total amount of coke produced and would contain about

1,125 to 1,175 pounds of clean coke, and 175 to 125 pounds of dust or breeze. The amount of breeze will vary with the manner in which the coke is handled, but should not run above the highest figure given. The amount of carbon specified is that removed from the retorts after scurfing and left for sale, and not the total amount actually deposited in the retorts.

Variations in the temperatures of the retorts affect principally the yield of gas and tar, and, to a slight extent, the quantity of ammonia produced. The higher the temperature the greater the amount of gas, and the smaller the amount of tar that is produced. At low heats the make of gas will not be over 9,000 cubic feet per ton, and there will be an increase in the amount of tar produced. The weight of coke is not much affected by the temperature of carbonization, though it will be slightly greater with low heats owing to the retention of a small amount of volatile matter that would be driven out by high heats. The effect of the temperature of the retort on the production of ammonia has not been as thoroughly determined as the effect on the yield of gas and tar, but a good authority (Mr. L. T. Wright) states that the production of ammonia is greater with medium heats than it is with either high or low heats. The production of carbon increases as the temperature of the retort rises.

56. A net ton of one of two gas coals that are available for use yields 9,000 cubic ft. of gas, 700 pounds of coke for sale, 11 gallons of tar and 4 pounds of pure ammonia, while a net ton of the other yields 9,800 cubic ft. of gas, 800 pounds of coke for sale, 12 gallons of tar and 5 pounds of pure ammonia. The average make per retort per 24 hours is 8,100 cubic ft. with the first coal and 8,820 cubic ft. with the second. In both cases retort house labor costs $4.00 per each six retorts per 24 hours and the prices for the products are: Gas, $1.25 net per 1,000 cubic ft.; coke, $4.00 per net ton; tar, 3 cents per gallon, and ammonia, 5 cents per pound. The first coal costs $2.50 per net ton. What is the equivalent price of the second?

Ans. To solve the problem set in the question it is necessary to determine the price at which the second coal would have to be bought, in order to make the cost of gas in the holder per 1,000 cubic ft. the same as it is with the first coal at $2.50. The only items in this cost that are taken as varying are the cost of coal and that of retort house labor. With coal No. 1 the net cost of coal, after deducting the value of the residuals produced, is:

Gross cost of coal		$2.50
Less—Coke 700 pounds @ $4.00 per 2,000 pounds	$1.40	
Tar, 11 gallons @ 3c.	.33	
Ammonia, 4 pounds @ 5c.	.20	1.93
Net cost of coal per ton		$0.57

As each ton of coal yields 9,000 cubic ft. of gas the net cost of coal per 1,000 cubic ft. is $\frac{57}{9} = 6.33$ cents. Since the retort house labor costs $4.00 per 24 hours for six retorts and the yield of gas per retort per 24 hours is 8,100 cubic ft., the cost of retort house labor per 1,000 cubic ft. is $\frac{400}{48.6} = 8.23$ cents. With coal No. 1 at $2.50 per ton the combined cost of coal net and retort house labor is therefore 6.33 cents + 8.23 cents = 14.56 cents.

In the case of coal No. 2, the cost of retort house labor being, as above, $4.00 per 24 hours for six retorts, and the yield of gas per retort per 24 hours 8,820 cubic feet, the cost of retort house labor per 1,000 cubic ft. is $\frac{400}{52.92} = 7.56$ cents. As the cost of retort house labor and the net cost of coal are assumed to be the only variable items in the cost of the gas per 1,000 cubic feet in the holder, the sum of these two items must be the same in the two cases to make this holder cost the same. Hence the net cost of coal per 1,000 cubic ft. must be 14.56 cents — 7.56 cents = 7.0 cents. The yield of gas per ton being 9,800 cubic ft. the corresponding net cost of coal per ton will be 9.8 × 7 = 68.6 cents, and the gross cost will be:

Net cost of coal		$0.686
Add—Coke, 800 pounds @ $4.00 per 2,000	$1.60	
Tar, 12 gallons @ 3c	.36	
Ammonia, 5 pounds @ 5c	.25	2.21
Gross cost of coal per net ton		$2.896

or say $2.90. That is, the cost of gas per 1,000 cubic ft. in the holder will be the same with coal No. 2 at $2.90 per net ton as it is with coal No. 1 at $2.50, and therefore $2.90 is the highest price per net ton that can be paid for coal No. 2 in competition with coal No. 1 at $2.50 per net ton.

57. In a coal gas plant the hydraulic main is D-shaped; the seals of the tar and liquor overflows are:—hydraulic main 18 in.; hot scrubber, 20 in. The dip-pipes are 30 in. long and dip 1¾ in. into the liquid in the hydraulic main. The internal area of each is 38 square inches. There are six to each section. The area of the liquor in the hydraulic main, outside the dip-pipes, is 18 square feet. One bench is idle. All the others are at work. There is a compensator and bye-pass on the exhauster, the bye-pass not automatic. The belt on the exhauster breaks. Where will gas show first? At what pressure will it appear at the mouthpieces of the idle retorts? What would you do upon discovering the trouble, if it was your duty to remedy it?

Ans. To simplify this problem we assume the pressure of the gas within the hydraulic main to be the same as that of the atmosphere, and that, therefore, the surfaces of the liquid in the main and in the dip-pipes of the idle bench are at the same level. We further assume that the liquid in the hydraulic main and in the seal pots has the same density as water.

The belt of the exhauster breaking and the generation of gas continuing, the pressure in the apparatus rises until an exit is forced and gas escapes into the atmosphere.

Gas will show first where the resistance to its escape is least and this will be through the shallowest seal between the hydraulic main and the exhauster, unless the conditions of size of hydraulic main and size and dip of the dip-pipes permit it to escape through the dip and stand-pipes before blowing either of the seals.

There are six dip-pipes—each with 38 sq. in. internal area, or 228 sq. in. area for six. To fill them one inch in height will take 228 cu. in. of liquor. The area of liquid outside the dips is 18 sq. ft. = 18 × 144 = 2,592 sq. in. The dip-pipes dip 1¾ in. Before gas can pass into the dip-pipes all the liquor in the main above their lower ends must be forced up into them. That is, the liquor covering 2,592 sq. in. of surface to a depth of 1¾ in. must be forced up six dip-pipes, having a total area of 228 sq. in. 2,592 × 1¾ = 4,536 cu. in. of liquor in the main above the lower ends of the dip-pipes. 4,536 ÷ 228 = 19.9 in., the depth to which the liquor in the main will fill the six dip-pipes before gas can reach their lower openings and pass up through the liquor. But the problem states that the dip-pipes dip 1¾ in. into the liquor. Therefore they contain 1¾ in. depth of liquor before that from the hydraulic main enters them. This added to 19.9 in. obtained as above gives 21.6 in. in depth to which the liquor would fill the dip-pipes before gas could enter. Any pressure in excess of this 21.6 in. will cause gas to bubble up through the dip-pipes.

The shallowest seal is at the hydraulic main overflow. It is 18 inches. Gas would show here first, as soon as the pressure exceeded 18 inches.

If this overflow were too small to carry off the gas, the pressure in the main would continue to rise until gas began to escape through the 20 in. seal of the hot scrubber, and if these two outlets did not sufficiently relieve the pressure, gas would, when the pressure had increased to more than 21.6 inches, escape up the dip-pipes of the idle benches.

If the caps had been removed from the bridge-pipes of the idle benches (which is good practice when letting down a bench), the gas that would otherwise appear at the mouthpieces would escape at the bridge-pipes.

Upon discovering the trouble at the exhauster the by-pass should be at once opened, to remain open until the reserve exhauster, if there is one, has been turned on, or the belt repaired and the stopped exhauster started. All the seals that have "blown" should be filled as soon as the bye-pass has been opened.

58. Describe one or more of the methods commonly employed for gasifying oil, when this is used for the direct enrichment of coal gas.

Ans. Oil gas for the direct enrichment of coal gas may be made in the following manner. One, or more, of the ordinary coal gas retorts are set aside for the purpose, and suitable pipe connections made between each one of these retorts and a small overhead oil tank holding from 50 to 150 gallons. In each connection there should be a siphon sufficiently long not to be blown by any pressure that is liable to exist in the retort under normal conditions. A valve should be placed on the oil pipe near the tank with another one near the retort. The oil may be fed to the retort by gravity alone, or it may be blown in with steam. In the former case a sight feed is desirable as it affords an opportunity to see at all times the rate at which the oil is being run into the retort. Such a feed can be made of a Mason fruit jar (see American Gas Light Journal, Vol. 74, page 605, or Progressive Age, Vol. 19, page 190), and should be placed next the oil valve nearest the retort and between this valve and the retort, but before the siphon. After passing through the sight feed and siphon, the oil flows into the retort by a pipe screwed into the side or top of the mouthpiece with a long thread, so that a coupling can be screwed on the end inside the mouthpiece. A short nipple with either a union, or long thread and coupling, on its other end is screwed into the coupling, then another nipple and an elbow pointing to the back of the retort. From this elbow a pipe, supported on bricks so as to clear the bottom by 3 or 4 in., is run to within 18 in. of the back of the retort, then turns and runs back to the front, then makes a second turn and runs back until its open end is about 1 ft. from the back wall of the retort. During its travel back and forth in the pipe the oil is vaporized by the heat to which it is exposed, and the vapor formed, escaping from the open end, is gasified in passing from the back to the front of the retort. The flow of oil is regulated to suit the heat, the correctness of the adjustment being determined by the appearance of the stain produced on a piece of white paper against which a jet of gas issuing from a small orifice in the retort mouthpiece or stand-pipe, is allowed to impinge. A dry straw-colored stain is obtained when the retort is working properly, while a greasy stain shows that too much oil is being run in, and a sooty stain that too little oil is being used. An expert oil maker can regulate the flow of oil by the appearance of the vapor as it issues from the orifice without the use of the white paper for obtaining a stain.

The pipe inside the retort should be 2 in. in diameter; that carrying the oil to the retort ¾ in. to 1 in.

When the oil is blown in by steam a steam connection is made to the oil pipe outside of; but near to, the retort in such a way that the stream of oil flows across the jet of steam and is thus picked up and carried along. A ½ in. steam pipe, with its end drawn down to an opening 1/16 in. to 1/32 in. in diameter, screwed into one end of a tee set with its run horizontal and its side outlet, into which the oil pipe is screwed, vertical, is very commonly used. After passing through the side of the mouthpiece, the ¾ in. or 1 in. oil pipe turns and running parallel to the axis of the retort passes through a cap on the end of a piece of 5 in. pipe and into the open end of a 2½ in. or 3 in. pipe fixed concentrically inside of the 5 in. pipe. The back end of the 2½ in. pipe is closed and the 1 in. pipe extends to within 3 or 4 in. of the closed end. As indicated above, the front is open and within 3 or 4 in. of the closed front of the 5 in. pipe, which has the back open and about 12 in. from the back of the retort. By this arrangement the oil and steam is made to travel back through the 1 in. pipe, forward through the annular space between this and the 2½ in. pipe, and then back through the annular space between this and the 5 in. pipe, from the open end of which it escapes as vapor to be gasified while passing along the retort to the mouthpiece and stand-pipe. The flow of oil is regulated by the same test as is used for the gravity feed, and as little steam is used as possible, the valve being barely raised from its seat. It is claimed that the use of steam prevents the pipes inside the retort from blocking up with carbon, otherwise it has no advantages, and the largest manufacturers of straight oil gas in this country prefer the gravity feed without any steam.

Another method of gasifying oil for the enrichment of coal gas is known as the "cartridge" method. In one modification of this method a cylinder, made by flattening and welding the ends of a piece of 3 in. or 4 in. pipe about 3 ft. long and provided with a circular opening in the side about $\frac{3}{4}$ in. in diameter, is filled with oil, the opening closed with a cork or wooden plug, and the loaded "cartridge" is then thrown into a retort on top of the coal when the retort is charged. The cork or wooden plug is carbonized by the heat, and as the oil vaporizes from the same cause the vapor escapes through the opening and mixes with the coal gas.

In another modification the cartridges consist of pieces of 2 in. or 3 in. pipe, 3 ft. or 4 ft. long, which are plugged at one end with a wooden plug and filled with sawdust. Oil is poured in until the sawdust is thoroughly saturated, then the open end is also plugged with a piece of wood and the "cartridge" is used as above.

This method may be useful as a temporary expedient, but if direct oil enrichment is adopted for regular use, it is better to make the oil gas in retorts set aside for that purpose, in which the oil can be gasified under properly regulated conditions that cannot be obtained when it is used in a retort charged with coal. Moreover, the extra labor required to fill and handle the cartridges is entirely avoided when the oil is run into the retorts by gravity.

59. What are the arguments for and against Anti-dips?

Ans. The principal arguments in favor of the use of Anti-dips, or arrangements for doing away with the liquid seal on the dip-pipes of coal-gas retorts while the retorts are closed and making gas, and either restoring this seal when the retort is out of use or open or else isolating the retorts at such times from the hydraulic or foul main by means of valves or other appliances, are that these Anti-dip arrangements prevent the excessive deposit of carbon in the retorts, that they improve the quality of the gas made, and that they lengthen the life of the retorts, other conditions remaining the same.

These advantages are supposed to spring chiefly from the fact that the removal of the seal allows the gas to flow out steadily and does away with the continual pulsations of pressure found in the retort when the gas has to force its way out through a liquid seal. "As the contact between the gases and the heated surface of the retort and its contents is the principal cause bringing about decomposition of the gas and vapor inside the retort, and, seeing that the effect of the seal is to cause the gases and vapors, from their elastic nature, to pulsate violently backwards and forwards along the roof and sides of the retort, it is evident that the gases and vapors traveling along the roof of the retort will be caused by this pulsating action to travel again and again over the same surface, and thereby be made to undergo repeated decompositions, and, consequently, an extra amount of carbon must be deposited." To test the truth of the theory thus stated by him, Mr. Young of Peebles, Scotland, experimented with a retort fitted with a piston so that violent pulsations of the gas could be produced, and found that working under the same mean pressure and similar conditions as to heat, carbon deposited to a depth, in places, of $\frac{3}{4}$ in. during six charges under pulsation, while when pulsation was avoided the deposit during the same number of charges was scarcely noticeable.

The more carbon deposited, over and above a certain amount derived from the decompositions necessary to produce fixed gas from the heavier vapors evolved during the earlier portion of the distillation, the lower the illuminating value of the gas. Further, with an Anti-dip arrangement in use, there is, of course, no danger of the gas having to bubble through tar and thus lose illuminating value.

The increased length of life of the retorts is considered to be due to the fact that the existence of a steady pressure in the retort allows the pores of the fire clay to become thoroughly saturated with carbon which cements the particles of clay together, making the material stronger.

It is argued against Anti-dips that as generally made they are very liable to get out of order from the deposition of tar and pitch on the valve faces and seats and on moving parts, thus causing more expense through breakage, loss of time and loss of gas by leakage than is saved by the removal of the seal; that unless automatic in action they require constant thought in order to prevent loss of gas or occurrence of accidents from neglect to manipulate them properly; that the passing of the gas through the liquid forming the seal to the dip-pipe is a necessary and valuable step in purification; and in general that when proper precautions are taken to prevent the accumulation of tar and to maintain an even, regular liquor seal, the hydraulic main and the dip-pipe are among the most simple and useful of gas works appliances, and there is no occasion for dispensing with them in favor of even the most approved form of Anti-dip.

There can be no question, however, that Anti-dip arrangements are employed with good results in many works, especially in Great Britain, and it seems as if on the whole the weight of evidence was in favor of their use when properly designed.

60. What is "coal liming"? Give its purpose and its effect on the impurities in the gas and on the residuals produced.

Ans. By "coal liming" is meant the mixing of a certain amount of slaked and powdered lime—usually about 3 per cent. by weight—with the coal before it is charged into the retorts. Its purpose is to reduce the amount of work on the purifiers by retaining a portion of the sulphur in the retorts in combination with the lime, and also to increase the yield of ammonia. It has been stated by a good authority as the result of experiment, that the life of the purifying material is doubled, the amount of ammonia in the gas greatly increased, and the quantities of carbon monoxide and carbon dioxide notably diminished. The appearance of the coke, however, is marred by white specks of lime, the amount of clinker is increased, and the quality of the coke impaired by the increased content of sulphur. The Trustees are not aware that the "coal liming process" is in use at this date in any gas works.

Impurities.

61. Name the chief impurities in crude coal gas as it leaves the retorts and give the reasons why they should be removed from the gas before it is distributed.

Ans. The chief impurities in crude coal gas as it comes from the retorts are: Tar, ammonia, NH_3, sulphuretted hydrogen, H_2S, and other sulphur compounds, and carbon dioxide, CO_2.

Tar should be removed by special appliances, since it is certain to condense when the gas cools, and unless it is completely and promptly separated from the gas while still hot it will absorb illuminants, thus reducing the candle power of the gas.

Ammonia should be removed on account of its corrosive action on brass and other metals employed in making meters and gas fixtures, on account of its pungent odor and on account of its marketable value.

Sulphuretted hydrogen and other sulphur compounds should be removed because if allowed to remain in the gas they will produce, when burned, sulphurous oxide, the substance formed by the combustion of sulphur, which is irritating to the lungs. Under favorable conditions the combustion of sulphuretted hydrogen may also form minute quantities of sulphuric acid. The amount of sulphur in gas as ordinarily purified, is too small to produce any appreciable effect.

Carbon dioxide is only harmful in so far as it reduces the illuminating value of the gas. The question of its removal or non-removal is usually decided by the comparative cost of such removal, and that of the extra enrichment required to overcome the loss of illuminating value.

62. Name three or more impurities in coal gas, as it comes from the condenser.

Ans. "Ammonia, carbon dioxide and sulphur compounds."

63. Describe the ordinary qualitative tests for the presence in gas of tar, ammonia, NH_3, carbon dioxide, CO_2, and sulphuretted hydrogen, H_2S, and state at what points in the apparatus the test for each should be made in order to determine that the gas is being properly purified. Give your reason in each case.

Ans. The ordinary test for tar is made by allowing a jet of gas to impinge on a piece of white paper. If a dark stain appears on the paper, tar is present in the gas. A continuous test for tar can be made by passing a stream of gas through a glass tube filled loosely with cotton wool. If tar is present in the gas, even if only to a very small extent, the cotton will be discolored.

The test for ammonia is ordinarily made by allowing a jet of gas to impinge on moistened turmeric paper, the turmeric paper turning brown if ammonia is present in the gas. Litmus paper reddened by a weak acid can be used instead of turmeric paper and will regain its original blue color if ammonia is present. The turmeric paper is more commonly used.

The following directions for preparing these papers are taken from Newbigging's Handbook:

"Turmeric Paper.—Six parts by weight of spirits of wine are added to one of turmeric powder in a stoppered bottle, and well shaken up occasionally for three days. A portion of the clear fluid is then poured on a plate, and pieces of unsized white filtering paper well soaked therein. These are then dried in air, cut into strips half an inch wide and two inches long, and kept for use in a bottle away from the light."

"Litmus Paper.—Six parts by weight of water to one of powdered litmus, shaken well together, allowed to stand for several days, and then filtered. Pieces of white filtering paper are then thoroughly soaked in the solution, dried, and cut into strips, which should be kept in a close stoppered bottle, excluded as much as possible from the air and light. Should it be desired to redden the solution, add (after filtration) a small quantity of very dilute sulphuric acid, gradually, drop by drop, until the pink or neutral tinge is obtained."

The test for carbon dioxide is made by allowing a small stream of gas to bubble through lime water. If carbon dioxide is present a white precipitate of carbonate of lime will be formed and the lime water will become cloudy owing to the diffusion of this precipitate throughout the liquid.

The test for sulphuretted hydrogen is made by allowing a jet of gas to impinge on a piece of white paper wet with a solution of acetate (sugar) of lead. The formation of a dark stain indicates the presence of sulphuretted hydrogen in the gas.

Since the object of all these tests is to determine whether or not the gas is being properly purified, the test for each substance should be made at the outlet of that piece of apparatus which is employed to remove the last traces of such substance from the gas. The proper place at which to test for tar is, therefore, the outlet of either the tar extractor or the condenser, according to which piece of apparatus is being used for the purpose of removing the tar. The test for ammonia should be made at the outlet of the last scrubber or the last washer, since any ammonia that escapes absorption in these vessels is lost so far as any return from it is concerned. The test for carbon dioxide and sulphuretted hydrogen should be made at that point in the series of purifiers at which it is desired that the purification should be complete. This is usually the outlet of the second box if three boxes are in use, and the outlet of the third box when four are being used.

64. What is naphthalene? What are its physical properties, and how are the obstructions caused by it removed?

Ans. Naphthalene is a hydrocarbon formed in comparatively small quantity (about 13.15 lbs. per ton of ordinary English coal distilled in coal gas retorts, according to Mr. R. W. Irwin) during the distillation at high temperatures of carbonaceous substances, such as coal and petroleum. It has been claimed that naphthalene can be formed in the gas after it leaves the retorts and during distribution, but this view is generally held to be incorrect, and from the present knowledge of the subject it seems practically certain that all the naphthalene found either in coal gas or coal tar is produced during the distillation of coal in the retorts. The molecule of naphthalene is composed of 10 atoms of carbon and 8 atoms of hydrogen, its chemical symbol being $C_{10}H_8$.

It is a solid at ordinary temperatures and pressures, melts at a temperature of 176° F. and boils at about 430° F. It will, however, exist in a state of vapor suspended in gas at temperatures far below even that at which it solidifies as long as the gas is not saturated with it. As soon as the point of saturation is reached, the vapor passes directly into the solid state in the form of very light, flaky, flat crystals, which occupy a large volume in proportion to their weight. It is this property which renders naphthalene so troublesome to the gas manufacturer, since though the weight contained in a given quantity of gas is small (about 0.15 lb. per 10,000 cubic feet of ordinary English coal gas, according to Mr. R. W. Irwin) the crystals occupy sufficient space to seriously obstruct the apparatus and pipes around the works and the services in which they are deposited through chilling of the gas.

Naphthalene obstructions in the apparatus and pipes at the works are usually removed either by flushing with hot water or by steaming, the former being preferable, since the steam merely melts the naphthalene, and unless it can escape from the pipe at once it may cool down again and solidify in another part of the apparatus, while the hot water acts not only by melting the naphthalene, but also by carrying it along, to a certain extent, in mechanical suspension. It is well to use the water in considerable volume in order to secure this latter effect.

Naphthalene is removed from service pipes and small mains by means of light naphtha, gasolene or kerosene, which is poured into and allowed to run through the pipes, dissolving the crystals and carrying the naphthalene in a liquid form back into the mains and the drips. Sometimes wood alcohol is used instead of naphtha or kerosene. If the obstruction is very light, it may be blown out of the service into the main by means of an air pump, or even by the lungs.

Naphthalene in the form of crystals, like water in the form of ice or snow, will pass from the solid state directly into that of vapor, and thus naphthalene that has been deposited in the pipes in quantities too small to cause trouble and render it necessary to clear it away will evaporate again and pass off with the gas when this reaches the deposit in an unsaturated condition. This same naphthalene may be re-deposited farther along in the system if the temperature changes so as to bring the gas again to the point of saturation with naphthalene, and it is probable that some action of this kind has given rise to the theory that naphthalene can be formed during distribution in a gas which was free from it when it left the holders.

Tar Extractors.

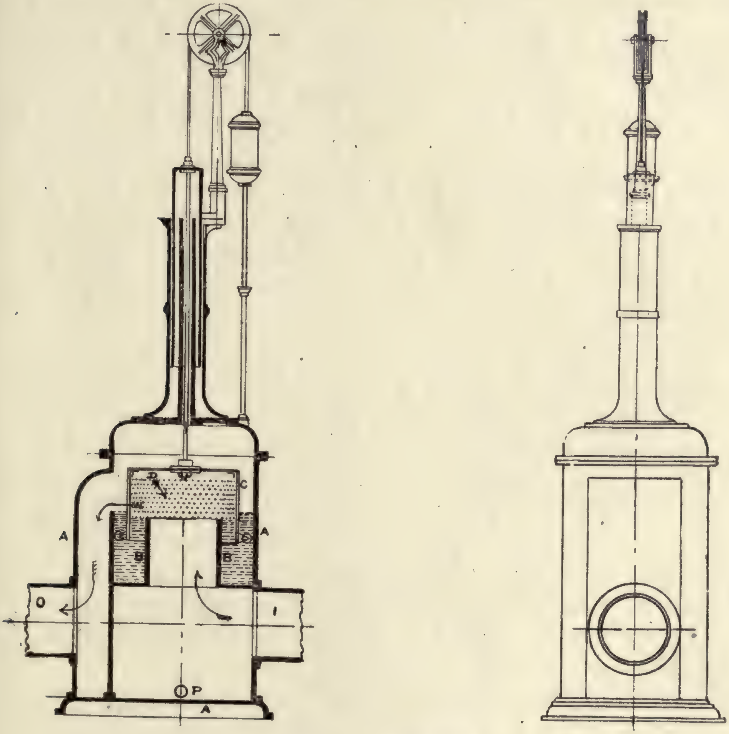
65. Describe a hot scrubber, its use and action.

Ans. If the vapors of tar which are present in coal gas in the hydraulic main could be carried by the gas to the consumer's burner they would be valuable as illuminants, but this cannot be realized because they liquefy at ordinary temperatures and form tar. This liquid tar condensed from the gas, if allowed to cool in contact, or to travel, with the gas, will absorb from the gas other light hydrocarbon vapors, which form, when burnt, the most useful light givers. It is, therefore, important to separate these vapors of tar from the gas as quickly as possible, and while it is still hot, so that the maximum of light hydrocarbon vapors will be retained in the gas. This is accomplished by the hot scrubber. The gas and tarry vapors leave the hydraulic main at a high temperature (between 110° and 150° F.), and pass into the hot scrubber. The gas should leave the hot scrubber at as near the entering temperature as possible. The hot scrubber may act on the principle of separation by friction, in which case the scrubber will consist of a shell filled with coke or wooden grids; or it may act on the principle of straining through small orifices and striking baffle plates, one type of such apparatus being the P. & A. condenser, described in the answer to question No. 66.

66. Give a description, illustrated with sketches if necessary, of one or more forms of apparatus for removing heavy tar from gas, and state the position in the sequence of apparatus that should be occupied by the tar extractors, with your reason for such location.

Ans. One method of removing tar from hot gas is founded upon the principle that deposition of the vesicles of tar held in suspension in the gas may be effected by bringing these vesicles into contact with solid surfaces, or with each other. The Pelouze and Audouin condenser, founded upon this principle and designed for use with hot gas, is a very efficient and compact form of apparatus for the removal of heavy tar from gas.

The action of the apparatus is as follows: The gas to be purified is made to flow through a series of holes of small diameter, so forming jets, which strike against a surface situated directly opposite. In the passage of the gas through the holes, the liquid molecules are brought into close contact with each other, and the operation is completed by the contact with the solid surface upon which the tarry matter is deposited.



P. AND A. CONDENSER.

The apparatus is represented in the cut, part shown a. broken away in order to explain more clearly its actions AAA is the outer case, to which are attached the inlet and outlet pipes, I and O. Concentric with the case is fixed an annular tank BB, in the middle of which is left a free passage for the gas. This annular tank is charged by preference with dead oil obtained from tar, and in it is suspended the bell or holder C, counterbalanced as represented.

The sides of the bell C for a portion of its height are formed of three or more concentric cylinders which are separated by a space of about three-eighths of an inch between them. Each cylinder is pierced, as represented at D, with a number of rows of holes each about one-twentieth of an inch in diameter, which are so placed that the gas in passing through the orifices of one of the cylinders impinges against the plate of the next; by this means all the tarry vesicles are broken up in a manner so complete, that when the apparatus is dispensed with, a piece of writing paper being exposed to the influence of the gas issuing from a small jet is, in the course of two or three seconds, rendered almost black by the deposit of the tar; whereas, when the condenser is in operation under like conditions, the paper is not soiled in the slightest degree. The tar is deposited on the side of the bell, whence it passes off by a suitable opening to the pipe P.

The bell, being balanced and free to move as shown, rises and falls automatically as the difference between the pressure inside and that outside of it increases or decreases, and so by the exposing, as the conditions demand, of a greater or smaller number of holes through which the gas can pass the pressure thrown by the apparatus is kept constant in spite of variations in the amount of gas made. A pressure gauge should be provided to show when this governing action is being interfered with by the clogging of the holes in the bell. When this occurs the holes should be cleaned, and the apparatus is so designed as to permit such cleaning to be done.

A form of apparatus known either as a hot scrubber or a dry scrubber is also used for this purpose. It consists usually of a rectangular shell, enclosing a space which is divided into several compartments, the gas passing through these compartments in succession. In each compartment is a series of plates so arranged that the gas is frequently baffled and forced to change the direction of its travel, and is at the same time exposed to friction in passing over the surface of the plates. The shock of the impingement on the baffle plates, added to the friction between the gas and the plates, causes the deposition of the tar just as in the P. and A. condenser. As, however, the gas is not divided into small streams, as in the latter form of apparatus, the dry scrubber must be made much larger if it is to handle the same quantity of gas per day.

The heavy tar extractor should be so located in the sequence of apparatus as to receive and treat the gas before it has been cooled down below 100° F. It may be placed after the exhauster when the gas leaves the latter at a temperature above 100° F., but should be placed before the exhauster when the gas leaves the latter at a temperature below that point.

The reason for so locating the tar extractor is that the heavy tar has, when cold, the property of absorbing from the gas the vapors of the lighter liquids, which vapors if not absorbed in this way would remain suspended in the gas. They are very efficient in adding to the light-giving value of the gas, and if the tar is allowed to absorb them the illuminating value of the finished gas is made lower than it will be when they are kept in it. At a temperature above 100° F. the tar does not seem to have any appreciable effect upon them, so if it is removed while the temperature is above that point it is prevented from exerting any harmful influence upon the illuminating value of the gas.

An ordinary tower scrubber filled with boards is used in carburetted water gas apparatus as a tar extractor, the boards being sometimes left dry, but usually wetted by a spray of water. In general, any form of washer may be used for the removal of heavy tar from the gas, provided hot ammoniacal liquor is employed as the liquid through which the gas is bubbled.

Exhausters.

67. Give one or more reasons why an exhauster is an advantage in a coal gas works.

Ans. "As the pressure in the retort can be reduced by the use of an exhauster, the amount of deposit of carbon in a solid state on the interior of the retort is lessened to a great extent, as the amount of deposit depends on the temperature and pressure to which the gas is exposed.

"The loss due to leakage is very much reduced, as a heavy back pressure would increase the loss.

"The amount of gas obtained is greater with the use of an exhauster than without it."

68. Should a coal gas exhauster be maintained at constant speed? If so, why? If not, why not?

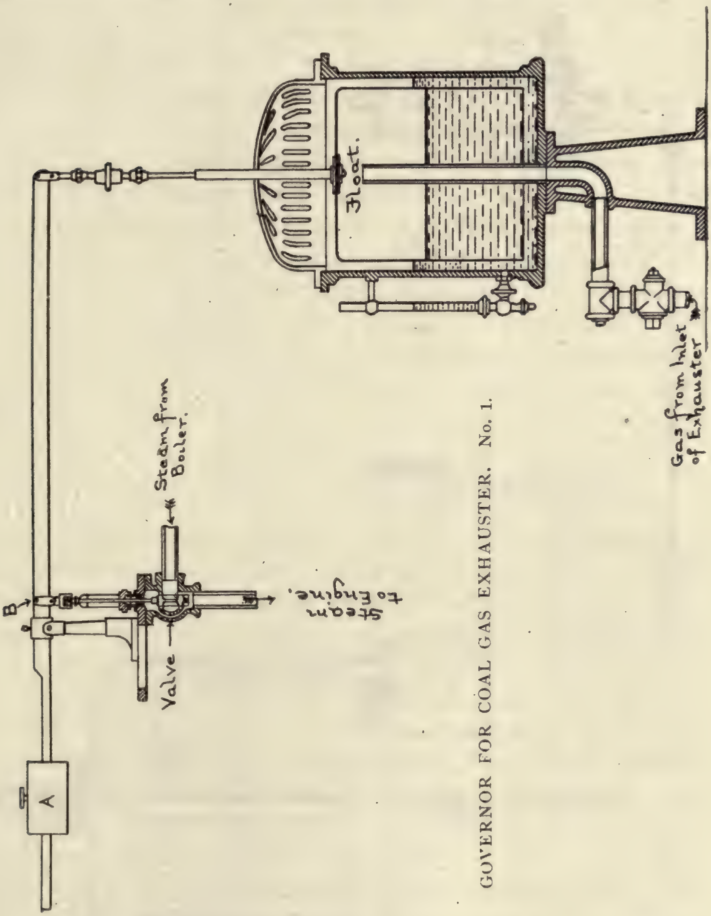
Ans. No.

The speed of the coal gas exhauster should vary as the quantity of gas being made varies, in order that the pressure of gas in the retort may be constant.

69. Give a description, illustrated by sketches, of the construction and operation of one or more forms of governor for regulating the speed of a coal gas exhauster so as to maintain a uniform pressure, or vacuum, on the hydraulic main.

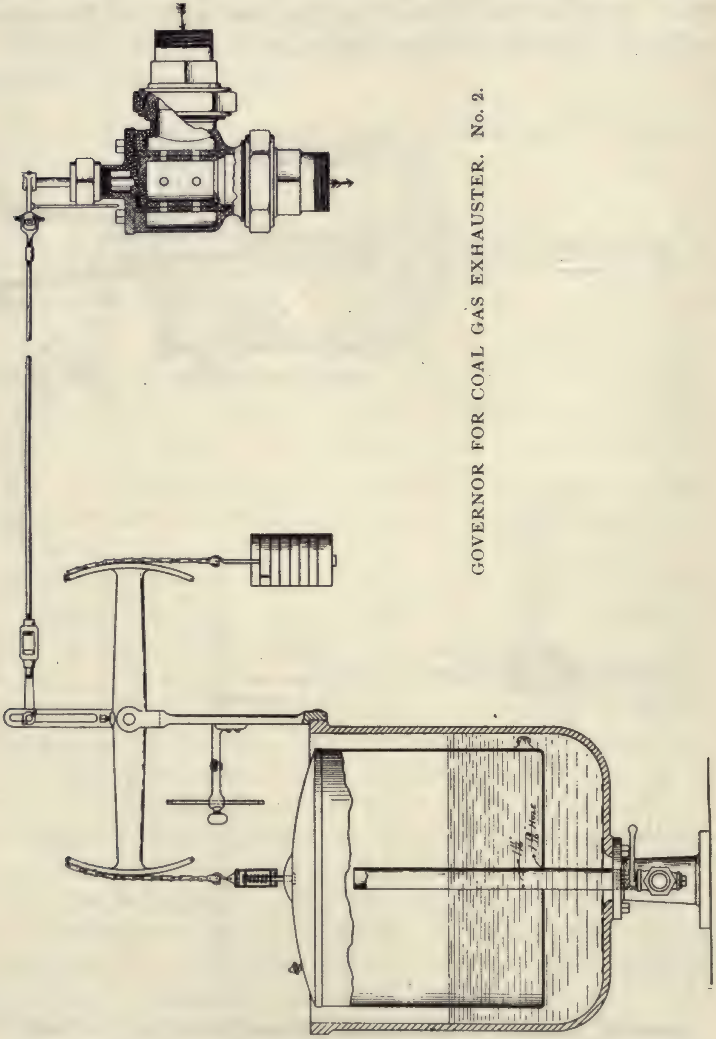
Ans. One form of such a governor is illustrated by the first of the accompanying cuts. The inlet of the exhauster is connected by a pipe, as shown, with the interior of a small holder or float, which is free to rise or fall in a vessel of water. This float is connected to a lever, as shown, and is balanced by a weight A on the end of the lever. At point B, attachment is made to a valve on the steam pipe from the boiler to the engine, the whole being so arranged that as the float rises the valve is opened, admitting more steam to the engine, and as the float falls, the valve is closed, reducing the amount of steam fed to the engine. If the make of gas increases, the pressure in the apparatus between the retort and the exhauster is increased, the pressure in the float is increased, and it rises, opening the steam valve and increasing the speed of the engine. The speed of the exhauster is thus increased, and the pressure at the inlet of the exhauster reduced to normal.

On cut No. 2 is shown another form of exhauster governor embodying exactly the same principles in a slightly different form of apparatus. In this case a rotary, instead of a lifting valve is used to regulate the amount of steam admitted to the engine and the up and down motion of the bell is transmitted to the valve, and changed into a horizontal rotary motion by means of a rocker arm and system of levers, as shown on the cut. Otherwise the action of the governor is exactly the same as that of the one described above.



GOVERNOR FOR COAL GAS EXHAUSTER. No. 1.

In order to obtain with these governors a close regulation of the vacuum, maintaining it between limits only two or three tenths of an inch of water apart, it is necessary that everything about them shall work freely and that there shall be no binding at any point. All bearings and places where there is any movement of one surface upon another must be kept well lubricated and must not be allowed to become gummed up. It is also necessary to restrict the rapidity of motion of the bell so that it will not move so rapidly as to

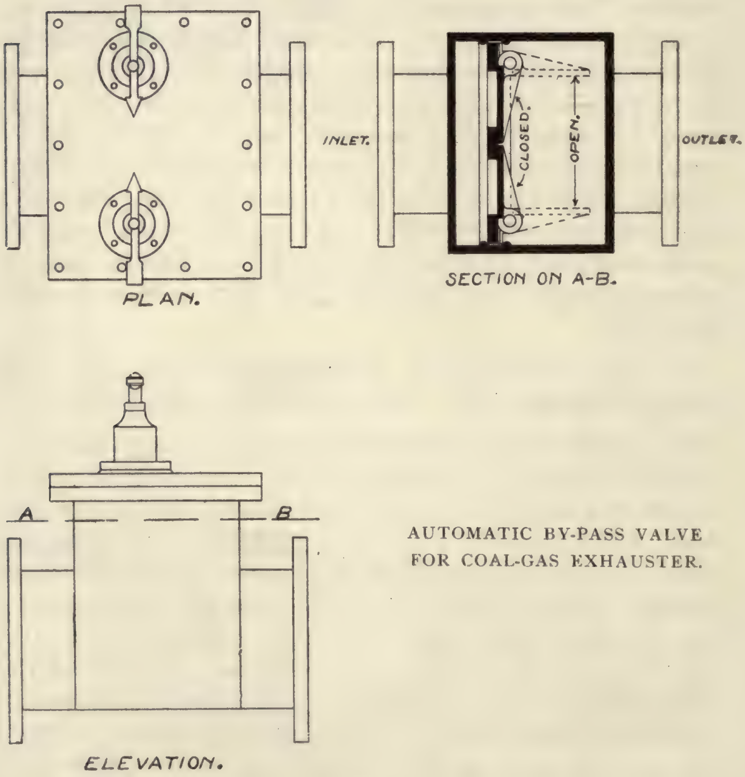


GOVERNOR FOR COAL GAS EXHAUSTER. No. 2.

carry beyond the desired point and thus keep the vacuum oscillating violently back and forth and so defeat its own object. This is done in the governor first described by having the stop cock on the pipe connecting the interior of the bell with the inlet to the exhauster, open only a very small amount so that gas can pass in or out at only a slow rate as the bell rises or falls. Small V-shaped grooves, filed one on each side of the hole through the plug of the stop cock, give openings with which the best results are obtained, the plug being set in such a position that the grooves alone come opposite the openings in the barrel, the main opening in the plug being entirely shut off except for the grooves. In the governor shown on cut No. 2 the same result is sought by making the bell with a closed bottom, as shown, and having the opening in this bottom, through which the pressure pipe passes into the bell, only a very little larger than the pipe. As the bell rises or falls, the water driven out, or drawn in, can pass through this opening only very slowly and consequently the bell can move at a slow speed only.

70. Give a description, illustrated with sketches, of an automatic by-pass valve for a coal gas exhauster.

Ans. The common form of automatic by-pass valve for a coal gas exhauster is often called a "butterfly" valve. It consists of a cast iron casing, either cubical or spherical, provided with flanges, by which it is attached to the pipe, and with a partition crossing it at right angles to the direction of the pipe. In this partition are two rectangular openings having their long edges vertical, and separated from each other by a strip of iron no wider than is necessary to allow for two narrow facings, one on each edge, which form part of the seats of two rectangular wing valves covering the openings. These valves are pivoted on their outer edges so that they open away from each other towards the sides of the casing. To each valve is attached a rod which comes through a stuffing box or a mercury seal in the top of the casing and has on it a short arm, serving both as a lever by which to open the valve and also as a pointer showing its position. The valve is set in the by-pass pipe with the side of the partition upon which the valves seat toward the outlet side of the exhausters and therefore the backs of the valves are subjected to the outlet pressure and their faces to the inlet pressure. As long as the exhauster is running the outlet pressure is the greater and keeps the valves firmly seated, but as soon as the exhauster is stopped for any reason the inlet pressure becomes greater than the outlet pressure, the valves are forced open and the gas can pass freely through the by-pass. The valves should be tried at regular and frequent intervals to see that they are not stuck to the seats and will be opened before the pressure rises to an excessive height.



PLAN.

SECTION ON A-B.

ELEVATION.

AUTOMATIC BY-PASS VALVE FOR COAL-GAS EXHAUSTER.

Washers and Scrubbers.

71. What part of a coal gas apparatus is especially designed for the removal of ammonia gas?

Ans. "Washer and washer scrubber."

72. In a coal gas apparatus what is a "washer"? What is a "scrubber"?

Ans. The washer is a vessel so constructed that the gas passing through it is made to bubble through water. The scrubber is a vessel in which the gas comes in contact with wetted surfaces. These surfaces may be stationary, and be kept wetted by a spray of water thrown over them; or they may, as in the so-called "mechanical scrubber," revolve around a central shaft, dipping in their passage into water, and rising from the water wetted, to come in contact with the passing gas. In a coal gas apparatus the washer is employed to remove ammonia, ammonia compounds, and whatever of tar may be in the gas at the time it reaches the washer, while the scrubber is employed only for the removal of ammonia and ammonia compounds.

73. Why are scrubbers for the removal of ammonia filled with coke or slats?

Ans. Ammonia is removed from gas by means of the affinity water has for ammonia. The gas is brought in contact with wetted surfaces of wood, coke or other material in cylindrical vessels called scrubbers. The greater the amount of wetted surface with which the gas comes in contact, the more efficient is the scrubber. It is important, therefore, that the filling material for scrubbers should present large surfaces to the gas, and should be of such a form, and so arranged, that the gas in passing through it would be broken up into many small streams. Coke, or wooden slats arranged in grids, answer these conditions, and, therefore, are the materials generally used in filling scrubbers for the removal of ammonia.

74. What are the various materials used for filling tower scrubbers and the respective advantages and disadvantages of these materials?

Ans. King's Treatise on Coal Gas mentions the following materials as being used for filling tower scrubbers when this form of apparatus was first employed: coke, small stones or pebbles, bricks, drain pipes, tiles and timber, and adds "or other material presenting a large surface to the action of water and gas." With longer experience coke came to be preferred on account of its lightness and also because it could be burned when removed on account of becoming clogged up with tar or naphthalene, and thus, since coke that would otherwise have been used for fuel was taken for refilling the scrubber, there was no expense incurred, either in cleaning it or in providing a new supply, as was the case when the other materials were used. The objection to coke was its liability to crumble under the weight of the coke above in the high column existing in the scrubber.

After scrubbers had been in use for some time, Mr. Geo. Livesey introduced the method of filling them with bundles of thin boards on edge which has since largely displaced the use of coke. Mr. Livesey used boards ¼ in. thick and 3 in. high, spaced ¾ in. apart and made up into bundles of a length and width suited to the diameter of the scrubber to be filled. As used at present in this country the boards are from ⅜ in. to ½ in. thick and 6 in. to 9 in. high, and are made up with ½ in. spaces between them. The bundles are built up tier by tier, each tier resting on, and being laid with the boards at right angles to, those in the tier below. At proper intervals in the height of the scrubber, supports are provided so that space can be kept between the adjacent tiers to permit a redistribution of the gas and also to allow the removal of part of the boards if necessary without disturbing the others.

Mr. Livesey calculated that for each cubic foot of space occupied,

Coke gives about 8½ sq. ft. of surface.

Boards give about 31 sq. ft. of surface.

Coke occupies ½ the cubical contents.

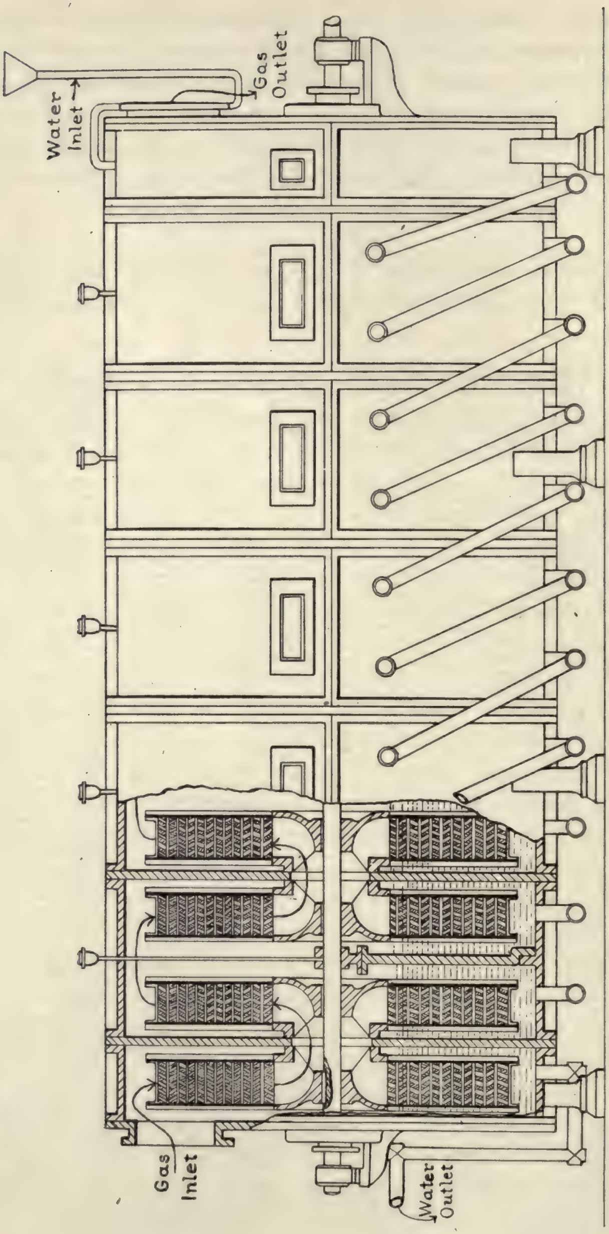
¼ in. boards spaced 1 in. centres occupy ¼ the cubical contents.

While it costs more to fill a scrubber with boards than it does to fill it with coke, the advantages of greater freedom from stoppages, capability of being cleaned without being removed, larger area of surface for contact between gas and water and the securing of a slower speed of travel of the gas by the smaller space occupied, possessed by the boards, more than counterbalance this excess in first cost and make the boards the best material for filling tower scrubbers.

75. Give a description, illustrated with sketches, of one or more forms of scrubbers used for removing ammonia from coal gas.

Ans. The scrubbers first employed in the manufacture of coal gas were of the well-known tower type, which in this country is still largely used in small works. These scrubbers consist of a shell of wrought or cast iron, either square or cylindrical, and ranging from 12 ft. to 60 ft. in height, the diameter being $\frac{1}{4}$ to $\frac{1}{5}$ the height. This shell is filled with some material which is of such a nature, and is so placed, as to form numerous narrow channels, in travelling through which the gas, which enters at the bottom and leaves at the top of the scrubber, is forced to pass over a large area of surface wet by water supplied in a suitable quantity and distributed over the top of the filling material in such a way that as it trickles down through this material all of the surfaces presented to the gas are kept thoroughly and uniformly wet. The proper distribution of the water over the material without the use of so much water as to make the resulting ammoniacal liquor very weak is one of the most difficult problems in connection with the working of tower scrubbers.

As usually built in this country at the present time these scrubbers have cylindrical wrought iron or steel shells, 3 ft. to 6 ft. in diameter and 12 ft. to 20 ft. high, and are filled with bundles of thin boards on edge, the boards being from $\frac{3}{8}$ in. to $\frac{1}{2}$ in. thick and 6 in. to 9 in. high and the bundles being made up with $\frac{1}{2}$ in. spaces between the boards and of a length and width suited to the diameter of the scrubber to be filled. These bundles are built up tier by tier, each tier resting on, and being laid with the boards at right angles to, those



ROTARY SCRUBBER.

in the tier below. At proper intervals in the height of the scrubber, supports are provided so that space can be kept between the adjacent tiers of boards in order to permit of a redistribution of the gas and also to provide for the removal of one set of bundles, if necessary, without disturbing the others. Various methods are employed to secure a uniform distribution of the water. One is to force the water in a single jet through a nozzle opening upwards in the centre of the scrubber and cause it to strike against a metal disc placed a few inches above the nozzle and thus to be broken up into a spray which falls very uniformly over the whole surface of the top tier of boards. Another is to allow the water to trickle through a number of small perforations made in pipes, which are inserted radially through the sides of the scrubber immediately beneath the top plate. Provision is made for the easy removal of these pipes to permit the examination of the perforations, and their cleaning in case they become clogged.

In larger works the tower scrubber has been almost superseded by some form of the more modern rotary or mechanical scrubber. One form of rotary scrubber is illustrated on the accompanying cut. The shell is of cast iron, and in shape is a rectangular prism surmounted by a half cylinder. It is divided into a number of compartments by means of plates at right angles to its axis, one set of these plates being the full size of the cross section of the shell and having circular openings, the centres of which are on the axis of the half cylinder, while those of an alternate set extend from the bottom to the top of the prism only. The shell is traversed lengthwise by a shaft, the axis of which coincides with the axis of the cylindrical portion, and which is supported by suitable bearings on the end plates and on the second set of cross plates mentioned above. On the shaft are fastened annular bundles of wooden slats, there being one bundle for each compartment of the shell, built up so that the gas can travel between the slats from outer to inner circumference of the bundles or vice versa, but not straight across the bundles parallel to the shaft. The central openings of the bundles are alternately closed and opened in such a manner in conjunction with the arrangement of the cross plates that, when the scrubber is filled with water to the proper level, the gas is forced to travel through the upper half of the bundles from circumference to centre, and from centre to circumference, alternately, as shown by the arrows.

Means, consisting usually of a small engine and the necessary train of gearing, are provided to slowly rotate the shaft and attached bundles. The spaces between the slats are very narrow, and thus the gas in passing through the scrubber flows in thin streams over surfaces kept continually wet by dipping into the liquor in the lower part of the shell as the shaft rotates. Water is admitted to the end opposite to that at which the gas enters and is carried by suitable overflows from one compartment to another until it finally leaves the scrubber at the gas inlet end. In this way the foul gas is caused to come in contact first with the strongest liquor, and then, as it passes through the scrubber and its content of ammonia decreases, with liquor of decreasing strength until, the ammonia having been all extracted, clean gas only enters the last compartment, which thus contains pure water.

Since these scrubbers are made with a comparatively large number of compartments it is possible to keep more than one clean and thus run no risk of losing any ammonia, and at the same time have sufficient scrubbing capacity to use only a small quantity of water and produce a correspondingly strong ammoniacal liquor.

76. Give a description, illustrated with sketches, of some device by which the water admitted to a tower scrubber can be distributed uniformly over the whole surface of the scrubbing material.

Ans. The greatest difficulty to be overcome in securing the even distribution over the whole surface of the scrubbing material, of the water used in a tower scrubber, is found in the small quantity of water which is used in proportion to the amount of surface to be wet. This is especially the case when no power for operating mechanical appliances is available except such as can be obtained from the water to be used. As this is the case in the majority of the gas works in this country, the devices employing outside power will not be considered in this answer.

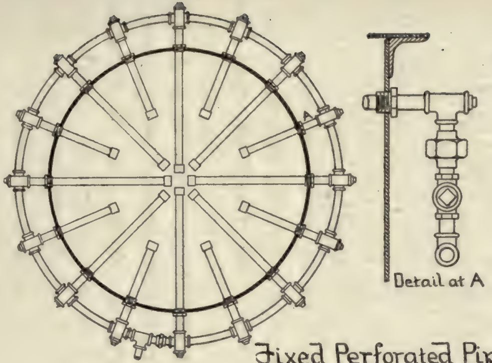
The principal devices by which distribution is secured by the energy of the water used may be divided into three classes, those in which a constant flow is maintained through fixed orifices, those in which a constant flow is maintained through orifices revolving about the centre of the scrubber, and those in which an intermittent flow through fixed orifices is employed.

In the first class belong the systems of fixed pipes inserted at equally distant points around the circumference of the scrubber just below the top head, with long and short lengths alternating, as illustrated in the cut, and pierced with small holes on the lower side through which the water issues. This arrangement is satisfactory when comparatively large quantities of water are used, as in water gas scrubbers or for coal gas scrubbers fed with ammoniacal liquor, but with the small flow required for coal gas scrubbers in which clean water is used, the pressure of the water must be kept so low that a majority of the holes soon stop up and the distribution becomes very uneven. Another device of this class is the Gurney jet, in which a jet of water issuing at a high pressure from a small orifice strikes against an inverted cup, or in some instances a flat plate, fixed a short distance above the orifice, and is broken up by the force of its impact into a fine spray which is scattered over a circular area having the jet as its centre. If the area of the scrubber is not too large, one jet, placed at the centre, just under the top head, is used, but in very large scrubbers it may be necessary to use several, properly distributed over the area.

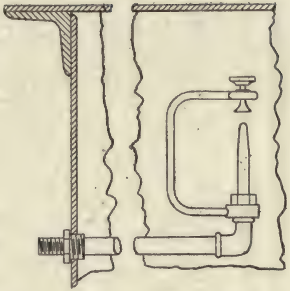
A device belonging to the second class which is frequently used is based on the same principle as the hydraulic tourniquet lawn sprinklers. It consists of a set of pipes radiating from a central fitting which is arranged so that it can rotate and at the same time be always open to a supply of water under pressure. Each pipe is pierced with holes on one side only, the various pipes being so fastened in the central fitting as to have the holes in all of them pointing in the same direction. When the water is turned on, it issues from the holes and the reaction against the opposite sides of the pipes, which are solid, causes the whole system to revolve. To produce an even distribution over the whole area, the distances between the holes are gradually reduced in going from the centre to the outer ends of the arms. In this form of distributor a good distribution can be secured with a smaller number of arms than when the pipes are fixed, and the greater flow through each orifice reduces the tendency for them to clog up, but it still exists to a certain extent. In another form belonging to the same class, the water is run into an overshot water-wheel made of heavy tin or galvanized iron and placed on top of the scrubber. This wheel drives the revolving distributor inside of the scrubber by means of bevel gears and a vertical shaft passing through a stuffing box in the head. The distributor consists of four or six radial arms, each of which is a shallow trough running out of a central trough. In the sides of these troughs notches are made through which the water runs out, the notches being closer together near the outer ends than they are towards the centre. Underneath the water-wheel is a funnel which catches the water dropping from the buckets. From this funnel a pipe with a syphon in it runs to the inside of the scrubber and delivers the water into the central trough of the distributor, from which it flows into the radial troughs and runs out through the notches. As the troughs are kept in motion as long as the water is flowing, this form of distributor gives a good distribution and is very free from any tendency to get out of order.

Devices of the third class consist of arrangements of tumbling barrels or syphoning chambers by means of which a comparatively large quantity of water is flushed into the scrubber at regular intervals. In the apparatus illustrated on the cut, a syphoning chamber is used. The water runs into the chamber continuously in a small stream, but none runs into the scrubber until the level rises above the top of the syphon. When this height is reached, the flow into the scrubber is started and is continued by the syphoning action until the lower end of the syphon is uncovered. The pipe through which the water flows being made large, say 2 in. in diameter,

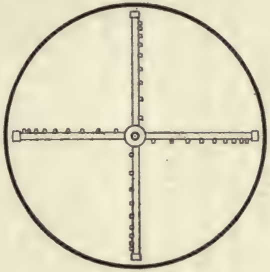
WATER DISTRIBUTORS FOR TOWER SCRUBBERS.



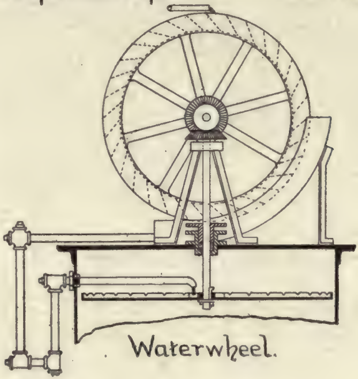
Fixed Perforated Pipes



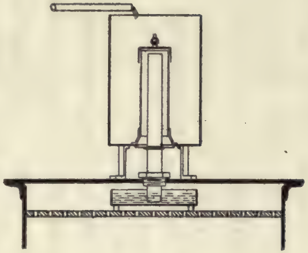
Gurney Jet.



Tourniquet



Waterwheel.



Syphoning Chamber.

the water is run into the scrubber at a high speed and overflowing from a sealing pan spreads over a wooden tray which is made the full size of the scrubber. This tray is perforated with small holes uniformly distributed over the whole surface, so that the water running through them wets the scrubbing material equally at all points. A small hole should be drilled at the top of the syphon, or an air cock should be attached at this point, to allow the air to escape from the syphon as the chamber fills up.

77. What is the object of the process of washing, or scrubbing, to which coal gas is subjected during its manufacture, and how and under what conditions of temperature should it be carried on to produce the best results?

Ans. The primary object of the process of washing or scrubbing coal gas is the removal from the gas of the ammonia which it contains. But, in all except the smallest works, there is a secondary object to be sought which is as important as the primary object, namely, to carry on the process in such a way that the ammonia be made to combine with, and remove from the gas, the greatest possible amount of carbon dioxide and sulphuretted hydrogen. The attainment of this object relieves the purifiers of much work that would otherwise be thrown upon them, whether they are used to remove both the impurities named or only the sulphuretted hydrogen. In the latter case it is especially important that the ammonia be made to combine to as great an extent as possible with the carbon dioxide, since in this case it is only by such combination that any of this impurity will be removed from the gas.

Water, having the property of absorbing ammonia in a volume large as compared with its own volume, and being cheap, is universally used in washers and scrubbers. As the volume of ammonia which a given volume of water can absorb decreases very rapidly with rise in temperature, it is necessary that the temperature of the gas be kept low during the process, a temperature of 60° being that at which it is usually carried on. To secure thorough saturation of the water and at the same time the complete removal of the ammonia from the gas, it is necessary that there should be intimate contact between the water and the gas and that they should flow through the washers and scrubbers in opposite directions in order that the clean water will meet nearly clean gas, and thus remove from it the last traces of ammonia, while the weak liquor first formed will, as it flows on, come in contact with gas containing more and more ammonia and thus become more and more saturated.

To secure the complete saturation of the ammonia with carbon dioxide and sulphuretted hydrogen, it is necessary to wash and scrub the gas with the ammoniacal liquor deposited in the hydraulic main and condensers. This liquor, owing to its having been formed at a comparatively high temperature, contains a large proportion of uncombined ammonia, which will combine with carbonic dioxide and sulphuretted hydrogen when brought into intimate contact with gas containing these substances, after it has been cooled. The hydraulic main and condenser liquor is used in the washer or scrubber into which the gas first enters after leaving the condensers, or if only a single scrubber of the rotary mechanical type is used, this liquor may be run in at about the middle compartment and allowed to flow toward the gas inlet end, clean water being run in at the gas outlet end and the resulting liquor allowed to go through all the compartments, being mixed with the hydraulic main liquor after passing the point at which the latter is admitted.

78. How should the process of washing and scrubbing coal gas be carried on to make the ammonia combine with the greatest possible amount of carbon dioxide and sulphuretted hydrogen and thus relieve the purifiers of work that they would otherwise be called upon to do?

Ans. In order that the ammonia in coal gas shall be made to combine with the greatest possible amount of carbon dioxide and sulphuretted hydrogen, it is necessary to so present to the gas the ammoniacal liquor formed in the hydraulic main and condensers as to give the uncombined ammonia, which forms a large proportion of the total amount of ammonia in such liquor, an opportunity to combine with the carbon dioxide and sulphuretted hydrogen in the gas.

The way in which this can be done depends upon the equipment of the works in scrubbers. If tower scrubbers are used at least two should be provided, the gas passing first through one and then through the other. In the first one that it enters the gas should be scrubbed with the liquor from the hydraulic main and condensers mixed with the weak liquor from the second scrubber in which clean water is used to remove the last traces of ammonia. If a rotary mechanical scrubber is used, the liquor from the hydraulic main and condenser can be introduced into, say, the middle compartment, where it mixes with the liquor formed in the compartments on the gas outlet end, at which clean water is admitted, and in connection with this liquor is used to scrub the gas as it passes through the compartments on the gas inlet end.

In England, where the gas coals contain more sulphur than do those used most extensively in this country and where, consequently, it is more important to make the ammonia combine with all the sulphuretted hydrogen that it can, tower scrubbers and mechanical scrubbers are sometimes used in series, the gas passing first through the tower scrubber, where it meets the hydraulic main and condenser liquor mixed with liquor from the mechanical scrubber, into which it passes after leaving the tower scrubber and which is supplied with clean water at the rate of from one to one and a half gallons per 1,000 cubic feet of gas made.

In places where the cheapest coals contain a comparatively large percentage of sulphur the cost of purification can be considerably reduced by so arranging and handling the apparatus as to take full advantage of the power of the ammonia to combine with sulphuretted hydrogen.

79. Describe one or more of the various methods employed to prevent the deposition of naphthalene in a solid state in the mains and services, and give the theory of the method described.

Ans. The various methods employed, or proposed, to prevent the deposition of naphthalene in a solid state in the mains and services may be divided into two general classes—those which remove the naphthalene from the gas at the works by means of some absorbent, and those which consist in adding to the gas vapors of liquids having a solvent action on naphthalene and approximately the same vapor tension as that substance.

Methods of the first class have been adopted quite generally on the continent of Europe and to some extent in Great Britain. In them the gas is washed or scrubbed with an oil which possesses the property of absorbing naphthalene vapor, the process being exactly similar to that by which ammonia is removed from the gas. The operation is usually carried on in a rotary, mechanical scrubber of the "Standard" type, in which either creosote oil, heavy tar oil or anthracene oil is used instead of water. A small amount of benzol, from 3% to 8% by weight, is added to the oil used, to saturate it and thus prevent it from absorbing benzol from the gas and reducing the illuminating power.

According to Dr. Bueb, at Dessau, Germany, an anthracene oil boiling between 480° and 750° F. is used, and 176.4 lb. (19 to 20 gallons) of this oil removed from 706,000 cu. ft. of gas naphthalene to the amount of about 200 grains per 1,000 cu. ft. The capacity of the oil for naphthalene increases with the temperature, and the naphthalene scrubber should follow the tar extractor and work on comparatively hot gas. In some cases, however, two or three compartments of the ammonia scrubber are used. After being saturated with naphthalene the oil can be put in a still and the naphthalene driven off, or it can be chilled, crystallizing the naphthalene, which is then removed by means of a filter press. In either case the oil can be used over again. If working on a small scale it may be more economical to run the saturated oil into the tar tank and sell it as tar.

The frequently employed method of running into the gas as it goes out into the district, naphtha which becomes vaporized and travels along with the gas, belongs to the second class. The naphtha is usually added to the gas at the outlet of the governor, being blown into the gas in a finely divided spray by a small steam jet atomizer. The success of this method depends upon the precipitation of the naphtha in liquid form at the time and place at which the naphthalene is deposited, so that the latter will be dissolved and carried off by the former, and as this does not always occur the remedy is not always successful.

A modification of the above method, known in England as the Hastings Carburation Process, consists in forming in the gas, as it goes out from the works into the street mains, a mist of oil, the oil used being one that is not volatile at ordinary temperatures. This mist, of very minute drops, is formed by blowing the oil through specially constructed atomizers by means of a portion of the gas which is compressed to a pressure of 75 lb. per square inch. It is found that in this state of minute subdivision some of the oil will remain in the gas until it reaches the farthest point in the district. The conditions which will cause the deposition of naphthalene at any point will also precipitate enough of the oil to dissolve this naphthalene and carry it off as a liquid. It is stated that at Hastings one gallon of oil used in this way for each 166,000 cu. ft. of gas is sufficient to do away with all trouble from naphthalene stoppages, although these begin to show as soon as the process is discontinued.

Much information on the subject of the prevention of deposits of naphthalene in street mains and services can be found in Vols. LXXII to LXXVI of the Journal of Gas Lighting.

Residuals; Coke, Tar and Ammoniacal Liquor.

80. Name some of the useful purposes to which the by-products or residuals of coal gas manufacture are applied.

Ans. *Coke:* Coke and breeze are used as fuel for manufacturing and domestic purposes.

Retort Carbon: Carbon is used extensively for electrical purposes

Coal Tar: Coal tar, in its crude state, is chiefly used as a preservative coating for wood and metal, for fuel, and for the manufacture of roofing felt. The distillates of coal tar are many. Among them are benzol, naphtha, benzine, creosote oils, anthracene oils and naphthalene. Benzine and anthracene are used in the manufacture of aniline dyes. Naphtha and benzine are used to enrich gas, as solvents for pigments in paints, and in rubber manufacture. Creosote is used to preserve wood and in the manufacture of carbolic acid. Naphthalene is used as an enricher of gas in so-called "Albo-Carbon" lamps, and to preserve fabrics from moths. The residue remaining after these substances have been driven off is called pitch and is used principally in roofing and in paving concrete.

Ammoniacal Liquor: From ammoniacal liquor are manufactured sulphate of ammonia, muriate of ammonia (sal-ammoniac) and other ammonia salts, and aqua ammonia. Aqua ammonia is used for cleaning wool and other fibres, in refrigerating and in the manufacture of ice and soaps. Sulphate of ammonia is used as a fertilizer and in manufacturing commercial soda. Sal-ammoniac is used in galvanic batteries and in the arts.

Spent Lime: Spent lime is sometimes used as a fertilizer.

Spent Oxide: Sulphuric acid and cyanogen are obtained from spent oxide.

81. Name some useful purpose, or purposes, to which tar (coal or oil) can be applied, either in or outside the gas works, and describe the method of preparation and employment for such purpose.

Ans. (A) As a paint.
(B) As a sidewalk pavement.

(A) The tar must have less than 1 per cent. of water in it to be readily boiled down without the use of special stills. Concentrate the tar by boiling until it will "string" between thumb and forefinger when cooled to 60° Fahr. When ready to use as paint, heat in quantity required for six hours' use, to about 150° Fahr. and stir in benzine in the proportion of one gallon to four of the tar. Apply hot, though as it gradually cools it can be used nearly as well, and sometimes the tar has been thinned as above while cold and used without heating, and has given satisfaction.

Naphtha is sometimes used instead of benzine. Paraffine oil is also employed as a thinner of the tar. Lime is also considered by some a necessary ingredient, but if used as mentioned here, the paint will prove durable and give a hard, smooth surface.

(B) For pavement for sidewalks, applied as a finishing surface two to three inches thick upon a foundation of broken stone or coarse clinkers, the top dressed with finer ashes or coke breeze, boil the tar until at 60° F. it has the consistency of vaseline. In the absence of special furnaces for the work, place a sheet of boiler plate upon stones, in the vicinity of the paving to be laid, so that it will be about one foot above the ground. On this plate throw building sand and underneath kindle a fire of wood or coke. Turn the sand over with a shovel until well heated. Gradually pour on the thick tar, meanwhile turning and mixing the mass until the sand is uniformly black and of such a consistency that a ball of it will just hold together while hot. While hot, and carrying the mixture in heated iron barrows or on shovels, apply where required, level with a hot rake and ram with a hot rammer. Then sprinkle the surface with fine sand and roll, using preferably a heavy hand roller. This may be made of a piece of cast iron street main, with ends plugged and centre filled with sand.

82. State the nature of the material to be employed and the points of valve design that should be observed in the pump end of a steam pump for handling tar.

Ans. All the parts of the pump end of a steam pump for handling tar should be made of iron, since the ammoniacal liquor, more or less of which is always mixed with the tar, would rapidly eat away any brass or composition which might be used for the cylinder lining or the valves.

The principal points of valve design to be observed are that the valves should afford full, free openings, and that the seats should be so arranged that no lumps of heavy tar or of solid matter in the tar will lodge on them and prevent the valves from closing tightly. A hinged valve is better than the ordinary form of pump valve, since in the latter form the centre guide obstructs the opening to a great extent, while the hinged valve affords a free and unobstructed opening. These valves are sometimes used with horizontal seats and sometimes with seats inclined at an angle of 45°. With the inclined seat there is less danger of any solid matter remaining on the seat and keeping the valve open.

A firm which handles a great deal of tar employs pumps in which the valves are hinged and the seats horizontal, and say that they have found them to give good satisfaction. In this case the valves are not provided with springs, being prevented from opening too far by stops and being closed by their own weight as soon as the pressure is removed from beneath them. In other pumps, springs are used with the same kind of valves to keep them from opening too far and to assist in closing them promptly when the plunger changes the direction of its travel. These springs should be made of iron or steel.

83. What are the different methods employed to determine the quantity of ammonia contained in ammoniacal liquor and consequently the value of the liquor, and which gives the most accurate results?

Ans. The most common and at the same time the least accurate method of determining the quantity of ammonia contained in any given sample of ammoniacal liquor, is to ascertain the specific gravity of the liquor by means of Twaddel's hydrometer, and then calculate the content of ammonia on the assumption that each degree Twaddel is equivalent to a strength of two ounces. This method is only approximately correct at best, and is far from accurate if the liquor contains any uncombined ammonia, since the greater the amount of such ammonia contained in the liquor the lower will be its specific gravity, and consequently the lower its value as indicated by the hydrometer.

A second method, which is also more or less inaccurate, according to the composition of the liquor, is to add sulphuric acid to a measured quantity of the liquor until the ammonia is just neutralized, the strength of the acid and the quantity of liquor being so chosen that the results are the same as if pure acid and a gallon of liquor had been taken, and, the quantity of acid used being accurately measured, calculate the amount of ammonia neutralized from this quantity. The source of error in this method is found in the fact that the "fixed" ammonia salts dissolved in the liquor are not affected by the sulphuric acid, therefore no acid is used in neutralizing the ammonia contained in these salts, and this ammonia is not included in the amount credited to the liquor. In fact, according to Mr. H. L. Greville, in a series of tests made by him, an average of 22.5 per cent. of the ammonia present in the liquors was not indicated by this method of testing.

The most accurate method of determining the true value of ammoniacal liquor is that which is known as the Wills or distillation test. In this a measured quantity of the liquor is mixed with a caustic alkali, usually soda, and then exposed to a strong heat for one or two hours. The soda combines with the acids of the ammonia salts in the liquor, setting free all the ammonia contained in the liquor. This ammonia passes off in the gaseous state and is absorbed in a solution of sulphuric acid, the amount of acid neutralized being accurately determined. As in the saturation test the quantity of liquor and the strength of the acid used in the test are so chosen that the results can be read off in terms of ounces of ammonia per gallon of liquor. This test gives an exact determination of the amount of ammonia contained in a liquor, and is the one which should be employed in all cases in which it is necessary to determine the value of a liquor as between buyer and seller.

84. What is meant by the expressions "five degree gas liquor" and "eight ounce gas liquor?"

Ans. The expression "five degree gas liquor" is used to denote an ammoniacal liquor, the specific gravity of which is such that a Twaddel hydrometer inserted in it will show a reading of five degrees. As there is a more or less close relation between the specific gravity of ammoniacal liquor and the amount of ammonia that it contains per unit of volume, this

Twaddel test affords a rough indication of the strength of any given liquor.

The hydrometer consists of a bulb loaded with mercury or shot, and surmounted by a hollow cylinder above which is a graduated tube, all being made of glass. The bulb is so loaded as to cause the hydrometer to be almost completely submerged when floating in distilled water with a temperature of 60° F. The point of the tube, which is even with the surface of the water, under these conditions, is marked as the 0 of the scale, which is then continued downwards on the tube in degrees and parts of degrees, each degree corresponding to an increase in the weight of the liquid of 5 ounces per cubic foot. The tube is usually made of such a length as to contain a scale reading to 25°. When the hydrometer is placed in a liquid heavier than water, such as ammoniacal liquor, the volume of liquid required to be displaced in order to float the instrument is, of course, smaller than the volume of water required for this purpose, and the hydrometer will not be as deeply submerged as it is in the water. The point of the scale which is at the level of the surface of the liquid when the hydrometer is floating at rest, and not in contact with the sides of the containing vessel, is noted, and the liquid is said to be of a corresponding number of degrees Twaddel strength.

The strength of ammoniacal liquor is commercially expressed also by the number of ounces by weight of pure monohydrated sulphuric acid, H_2SO_4, of 1.84 specific gravity, which is required to saturate the ammonia contained in one gallon of the liquor. The expression "eight ounce gas liquor" thus denotes an ammoniacal liquor which contains per gallon a quantity of ammonia which requires eight ounces of pure monohydrated sulphuric acid of 1.84 specific gravity for its neutralization.

In determining the strength in ounces of any sample of ammoniacal liquor, accurate results cannot be obtained by adding the acid directly to the liquor. It is necessary to distil the liquor after adding to it a caustic alkali, such as caustic soda or milk of lime, and to use the acid to neutralize the ammonia as it is driven off by this distillation.

It is commonly considered that each degree Twaddel corresponds to a strength of two ounces, but this is only an approximation, and the strength of ammoniacal liquor should always be determined by the distillation test, which should be specified in all contracts for the sale of such liquor.

85. In the answer to question No. 55, the yield of ammoniacal liquor per net ton of coal is given as 27 gallons of from 6 ounces to 8 ounces strength. How many pounds of pure ammonia gas, NH_3, does this amount of liquor represent?

Ans. Since the term ounce as used in designating the strength of ammoniacal liquor means that a gallon of the liquor contains for each ounce strength, the quantity of pure ammonia that will neutralize one ounce of pure monohydrated sulphuric acid, H_2SO_4, with a specific gravity of 1.84, each gallon of 6 to 8 ounce liquor will contain an amount of ammonia that will neutralize 6 to 8 oz. of sulphuric acid.

The reaction between ammonia, NH_3, and sulphuric acid, H_2SO_4, takes place according to the following equation, $2NH_3 + H_2SO_4 = (NH_4)_2SO_4$. The proportions by weight in which substances combine with each other can be determined from the molecular weights shown by the equation to enter into the reaction according to which the combination takes place. As the atomic weight of nitrogen, N, is 14, that of hydrogen, H, is 1, that of sulphur, S, is 32 and that of oxygen, O, is 16, the proportion by weight in which ammonia and sulphuric acid combine will be $2(14 + 3) = 34$ parts of ammonia and $(2 \times 1) + 32 + (16 \times 4) = 2 + 32 + 64 = 98$ parts of sulphuric acid. One ounce of the latter will therefore combine with $\frac{34}{98} = 0.3469$ oz. of the former, and ammoniacal liquor will contain 0.3469 oz. of ammonia per gallon for each ounce of its strength. Or in other words, the number of ounces of ammonia contained in a given number of gallons of ammoniacal liquor of a given strength is equal to the continued product of the number of gallons, the strength in ounces and 0.3469.

27 gallons of 6 ounce liquor will therefore contain $27 \times 6 \times 0.3469 = 162 \times 0.3469 = 56.19$ oz. or 3.51 lb. of

ammonia, while 27 gallons of 10 ounce liquor will contain $27 \times 8 \times 0.3469 = 216 \times 0.3469 = 74.93$ oz. or 4.68 lb.

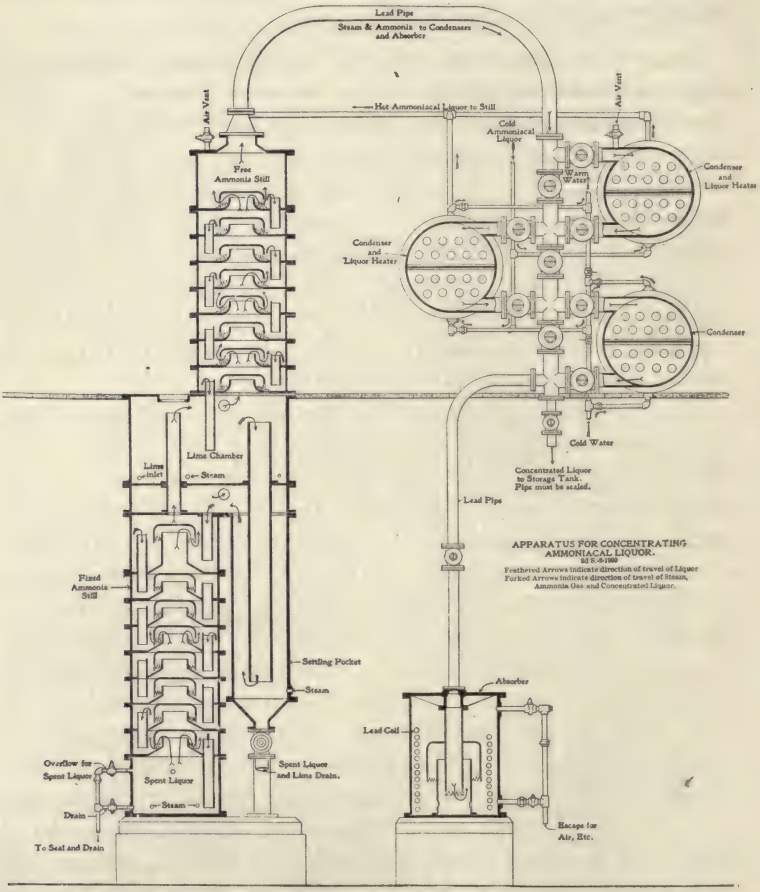
86. Give a description, illustrated by sketches, of some form of apparatus for, and the process of concentrating ammoniacal liquor and state the conditions that render it advisable to so treat the liquor.

Ans. The apparatus used for concentrating ammoniacal liquor consists essentially of one or more "stills" in which the ammonia is driven out of the liquor either by heat alone or by the combined action of heat and a solution of lime, one or more "coolers," or condensers, in which the mixture of ammonia gas and water vapor passing off from the still is cooled and condensed into strong ammoniacal liquor, and one or more "absorbers," or catch vessels, in which any ammonia gas that escapes from the coolers is absorbed in cold water in a manner similar to that in which the ammonia is removed during the process of gas manufacture.

The apparatus illustrated in the cut is composed of two stills, three condensers so connected that either one, two or all three may be used at any time, and one absorber. In one of the stills the "free" ammonia (that is, the ammonia existing in the liquor either in an uncombined state or in the form of carbonates or sulphides, with occasionally a little cyanide or acetate), which can be driven off by heat alone, is expelled, the other still being used for driving off "fixed" ammonia or ammonia so combined (chiefly as chloride or thiosulphate with some thiocyanide and ferrocyanide, sulphate, sulphite and in very fresh liquor thiocarbonate) that some alkali must be used in order to enable the heat to set free the ammonia. The liquor connections are so arranged that the liquor on its way from the storage tank to the stills passes through the tubes of either one or two of the coolers and thus absorbs, and returns to the still, heat that would otherwise be imparted to the water used for cooling and lost.

In a more simple form of apparatus the two stills are combined into one, and the condensers replaced by a coil of lead pipe immersed in a vessel, through which water is kept flowing.

By referring to the cut it will be seen that the stills are composed of a number of separate chambers, each of which has a circular opening raised above its bottom and so covered with a hood, the edges of which are serrated, that any gas or vapor flowing through the opening can only pass out under the edge of the hood, which edge is kept sealed in liquor. The coolers are similar to the ordinary multitubular condensers used in gas manufacture, but the tubes should be made of some mate-



APPARATUS FOR CONCENTRATING AMMONIACAL LIQUOR.
2d S.-2-1900
Feathered Arrows indicate direction of travel of Liquor
Forked Arrows indicate direction of travel of Steam, Ammonia Gas and Concentrated Liquor.

rial that is not affected by ammonia and not of wrought iron or steel. The absorber is merely a washer in which the gas has to pass through the water twice. All connecting pipes which carry ammonia and steam, or strong liquor, should preferably be made of lead, and special stop cocks made of materials not affected by ammonia should be used.

The apparatus is operated as follows :

A supply tank is kept filled with ammoniacal liquor while the concentrator is kept running. The water space of the first cooler is filled with the weak liquor to be concentrated, or this space in both the first and second coolers may be so filled, while that in the other cooler is filled with cold water. The absorber is also filled with water. Steam is then turned on at the bottom of the fixed ammonia still, the air being blown out of the apparatus by the air vents on the free ammonia still, the first cooler and the absorber, and the apparatus is heated up. When the proper temperature has been reached, say about 175° F. at the inlet to the first cooler; the liquor cocks are opened and liquor run from the supply tank through the cooler, or coolers, into the still. A current of water is also started through the coolers not being used as liquor heaters. The hot liquor running into the top of the still fills up the first compartment, overflows into the second, fills this up and overflows, and so on down through all the compartments of the free ammonia still into the lime chamber, through the lime settling pocket into and through the compartments of the fixed ammonia still, as indicated on the cut by the feathered arrows. The steam bubbling through the liquor, as it fills one compartment after the other, heats it more and more, until by the time the liquor has reached the lime chamber the free ammonia has all been driven off. Milk of lime added at this point decomposes the fixed ammonia compounds, and as the ammonia passes through the fixed ammonia still, it parts with the remaining ammonia under the action of the heat and reaches the bottom of the still spent and ready to be run through the sealed overflow to the drain.

The steam and the ammonia gas pass upward, as indicated by forked arrows on the cut, bubbling through the liquor in each compartment, which in each case absorbs a little of the ammonia to give it off again at the higher temperature met with in the compartment next below, until finally the steam and the remaining ammonia gas pass out together from the top of the still and enter the coolers. As the mixture cools the steam condenses, and in so doing absorbs the ammonia gas in greater and greater quantity as the temperature falls, until at the outlet of the last cooler most of the ammonia has been absorbed and the concentrated liquor so formed is drawn off to the storage tank. As it is not advisable to have the temperature at the outlet of the coolers reduced to too low a point, some of the ammonia gas is still unabsorbed at this point, but is caught by the water in the absorber, this water being kept cool by circulating cold water through the coil with which the absorber is provided. The liquor thus formed in the absorber should be drawn off and replaced by fresh water as soon as it reaches a strength of 2° Twaddel.

The strength of the concentrated liquor is tested occasionally and kept at the proper point by adjusting the flow of liquor and of steam. The more steam used for the same amount of liquor the weaker is the concentrated liquor. The more weak liquor used for the same amount of steam the stronger is the concentrated liquor. If too much weak liquor, or too little steam is used, all the ammonia will not be driven off from the spent liquor, which will carry some of the ammonia out with it from the still. When this is the case the spent liquor running off will smell of ammonia.

Some hints as to the points to be watched in starting up, operating and letting down an ammonia concentrating apparatus will be found in a paper read before the Michigan Gas Association, at its Seventh Annual Meeting, by Mr. George Osius, and published in Progressive Age, Vol. XVIII, page 90, and the American Gas Light Journal, Vol. LXXII, page 449.

The principal condition rendering it advisable to concentrate ammoniacal liquor is remoteness from a market in which this liquor can be sold. In this case the reduction in cost of transportation owing to the concentration becomes an important item in permitting the ammonia to be sold at a price that renders it worth handling. It has been stated that a works carbonizing as low as 750 tons of coal per annum can net a profit from concentrated ammonia that will pay at least 15% interest on the cost of the necessary apparatus. Of course, this figure depends somewhat on the location of the works and upon the amount of money put into the apparatus.

87. What is the common method of manufacturing sulphate of ammonia, and what are the chemical reactions that occur in the process?

Ans. The manufacture of sulphate of ammonia depends on the chemical facts that all compounds of ammonia are decomposed when heated with an alkali, free ammonia being liberated, and that sulphuric acid combines with ammonia to form sulphate of ammonia. The chemical changes involved may be represented as follows:

$(NH_4)_2CO_3$	+	$Ca(OH)_2$	=	$CaCO_3$	+	$2H_2O$	+	$2NH_3$
Carbonate of ammonia		Hydrate of lime		Carbonate of lime		Water		Ammonia

and

$2NH_3$	+	H_2SO_4	=	$(NH_4)_2SO_4$
Ammonia		Sulphuric acid		Sulphate of ammonia

In the operation as conducted by the intermittent system, the gas liquor is pumped into a still and heated by admitting live steam at the bottom of the still. On heating the mixture, free ammonia is disengaged, together with large volumes of sulphuretted hydrogen and other foul gases. When all, or nearly all, the free ammonia and that in the volatile compounds of ammonia have been driven from the liquor, cream of lime is added to free the ammonia from the fixed ammonia salts held in solution in the liquor. The acids of the salts combine with the lime, and the ammonia is liberated. The lime salts remain in the liquor. The ammonia and other gases leaving the still pass to a "saturator" containing sulphuric acid, through which they bubble. The ammonia is retained by the acid, forming sulphate of ammonia, which crystallizes and settles out from the solution and is ladled out and dried. The foul gases after leaving the saturator are either burned, or absorbed by oxide of iron, in order to prevent a nuisance.

In the continuous system, a still similar to that employed for concentrating liquor is used, and the ammoniacal liquor is treated with steam and milk of lime as when it is to be concentrated. The gas escaping from the stills passes first through a baffle box for the removal of moisture, and then into the saturator as in the intermittent system. The waste gases from the saturator pass into the liquor heaters and impart their heat to the liquor flowing into the still, after which they are either burned, or absorbed by iron oxide as in the intermittent system.

The continuous system is more economical, since the greater part of the heat in the waste gases is recovered, but the apparatus necessary is not as simple as that employed in the intermittent system.

88. Five pounds of ammonia gas, NH_3, are produced by, and collected in the ammoniacal liquor resulting from, the carbonization of a net ton of coal, and this liquor is used for the manufacture of sulphate of ammonia with a loss of 5% in the process of manufacture. How much dry sulphate of ammonia will it yield, and how much pure sulphuric acid will be used in the operation, assuming no waste of acid? Give your calculations.

Ans. Since 5% of the ammonia is lost in the process of manufacture the amount of ammonia converted into sulphate is 95% of 5 lb. or 4.75 lb. The formula of sulphate of ammonia is $(NH_4)_2SO_4$ or two molecules of ammonia gas, NH_3, unite with one molecule of sulphuric acid, H_2SO_4. A molecule of ammonia gas being composed of 1 atom of nitrogen and 3 atoms of hydrogen, and the atomic weight of nitrogen being 14, and that of hydrogen being 1, the atomic weight of a molecule of ammonia gas is—nitrogen, 14; hydrogen, 3, total 17. The atomic weight of 2 molecules is therefore 34. The atomic weight of hydrogen being 1, that of sulphur 32, and that of oxygen 16, sulphuric acid, being a combination of 2 atoms of hydrogen, 1 atom of sulphur and 4 atoms of oxygen, has an atomic weight of 98, and the atomic weight of sulphate of ammonia will be 98 + 34 = 132. Therefore, 34 lb. of ammonia combine with 98 lb. of sulphuric acid to form 132 lb. of sulphate of ammonia, and 34/132 of sulphate of ammonia, or 25.75%, will be ammonia gas. Since 34 lb. of ammonia, combined with sulphuric acid, will produce 132 lb. of sulphate of ammonia, 4.75 lb. of ammonia gas will, combined with sulphuric acid, form $\frac{132 \times 4.75}{34} = 18.44$ lb. of ammonia sulphate. Of this 4.75 lb. being formed of ammonia gas, the remainder, or 13.69 lb., is formed of sulphuric acid. The percentage of ammonia gas in pure sulphate of ammonia is 25.75 by weight. We may, therefore, prove our problem by multiplying 18.44 by 0.2575, which gives us 4.748, or within 0.002 lb. of the 4.75 lb. of ammonia gas with which we started our problem. The slight difference is due to our not having carried the decimals in our divisions further than the second place.

89. Does coke deteriorate while stored? If so, why, and how?

Ans. Coke when stored crumbles from exposure to rain and frost, and from the crushing effect of its own weight, to fine particles of less value. The fine particles or dust are called "breeze" and for fuel purposes are of less value than the lumps.

90. What is the difference in general character between gas house coke and oven coke, and, in general terms, how is each made?

Ans. "Gas house coke is made as a by-product in the manufacture of coal gas, and is that portion of the charge remaining in the retorts after the gas has been driven off.

"There are various forms of ovens used in making oven coke, but that known as the 'bee-hive' oven is by far the most generally employed. As its name implies, the interior of this oven is dome-shaped, precisely like a bee hive, and is generally built from 11 to 12 feet in diameter, and from 5 to

6 feet in height. The working is very simple, depending on the principle that the heat necessary for the coking of the charge is supplied by the combustion in the oven itself of a portion of the escaping gases and more or less of the fixed carbon of the charge. The coal is dumped through an opening in the crown of the oven, and spread evenly on the floor to an average depth of about 2 feet. The front opening through which the coke is discharged is at first nearly closed with brick, luted with loam. The heat of the oven from the previous coking fires the charge, and as the coking progresses the air is more and more shut off by luting the openings and finally closing the roof openings. The average charge is 7,600 lb., and the time of coking is 48 hours, with 72 hours for that burned over Sunday. When the coke is thoroughly burned, the door is removed, and the coke is cooled by water thrown in from a hose, and then drawn.

"Gas house coke is comparatively soft and friable, due chiefly to the short time occupied in burning off the charge—from 4 to 6 hours—also to the lower temperature of carbonization, whereby the volatile constituents of the coal have not been driven off as completely as in oven coke.

"Oven coke is porous in structure, but very hard, with a metallic ring and a bright silvery-gray lustre."

Oven coke is also made in ovens designed to enable the operator to utilize the gas, tar and ammonia produced.

91. With a good market for coke at 18c. per hundred pounds, what is the value of tar as a fuel for heating retort benches?

Ans. The advisability of using tar to replace coke as the fuel for retort benches when the market for tar was poor and that for coke good, has been frequently discussed at the meetings of the various gas associations, but in only a few cases have definite figures been given as to the amount of tar required to do the same work as a given amount of coke, and the figures given vary somewhat from each other. In a discussion at the meeting of the American Gas Light Association held October 18th, 1876, Mr. Chas. H. Nettleton stated that experiments he had made showed that 2.6 gallons of coal-tar were equal to one bushel of coke for heating retorts, and Mr. W. H. Pearson said that he considered 2.5 gallons as the equivalent of a bushel of coke for this purpose, while according to Mr. Chas. Nettleton only 2 gallons were required to do the work of a bushel of coke. These figures were for direct-fire benches. In 1899 Mr. F. C. Sherman told the New England Association of Gas Engineers that in half-depth (semi-recuperative) furnaces he was using 200 gallons of tar (presumably coal-tar) to replace 72 bushels of coke, or 2.76 gallons for each bushel. In 1901 the same authority said that 150 gallons of water-gas tar (oil-tar) were equivalent to 66 bushels of coke, or 2.27 gallons for each bushel.

It is therefore safe to take 2.5 gallons of coal-tar as being a fair equivalent in actual working for one bushel of coke as bench fuel. A bushel of coke taken just as it comes from the retorts will weigh on an average 38 lb. If coke is worth 18c. per 100 lb., one bushel weighing 38 lb. will be worth $\frac{18}{100} \times 38 = 6.84$c., and therefore the equivalent value of tar will be $\frac{6.84}{2.5} = 2.74$c. per gallon. If 2.27 gallons of tar are taken as being able to do the work of one bushel of coke, then the tar, whether coal-tar or water-gas tar, is worth, with coke at 18c. per 100 lb., $\frac{6.84}{2.27} = 3.01$c. per gallon.

While figures obtained from experiments on the heating of boilers are probably not strictly applicable to bench heating, they may be used as a check on the figures given above. Mr. C. F. Prichard, in a paper on the Fuel Value of Residuals, read before the American Gas Light Association in October, 1901 (see Proceedings of the Association, Vol. XVIII, page 77; American Gas Light Journal, Vol. LXXV, page 807, and Progressive Age, Vol. XIX, page 517), gives the equivalent values of coke, coal-tar and water-gas tar for boiler fuel as $3.75 per ton (2,000 lb.) of coke, $1.17 per barrel (50 gallons) of coal-tar, and $1.39 per barrel of water-gas tar. With coke at 18c. per 100 lb., or $3.60 per 2,000 lb., the values of 50 gallons of coal-tar and of the same amount of water-gas tar would be $\frac{1.17 \times 3.60}{3.75} = \$1.12$ and $\frac{1.39 \times 3.60}{3.75} = \$1.33$, respectively, or 2.5c. and 2.96c. per gallon. Mr. Prichard stated that the experiments from which the value of the coal-tar was determined were not entirely satisfactory, and he thought that the true value per gallon was practically the same as that of water-gas tar.

According to these figures the relative value of the tar as compared with coke is a little lower when it is used as boiler fuel than when used as bench fuel, but the difference is not very large, and the two sets of experiments seem to check each other fairly closely.

PART 2.—DISTINCTIVELY CARBURETTED WATER GAS.

Generating Apparatus.

92. Two distinct types of apparatus, which may be called the generator-superheater and the generator-retort types respectively, are used for the manufacture of carburetted water gas. How do they differ from each other and which is the most extensively used at the present time?

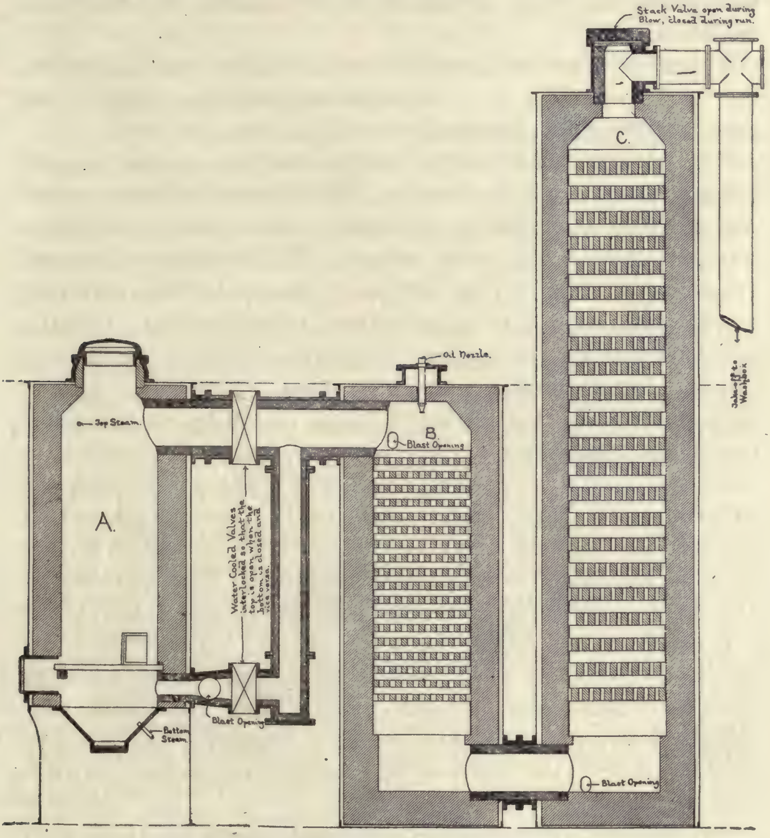
Ans. The essential difference between the generator-superheater and the generator-retort types lies in the method employed to produce the oil gas necessary to carburet the water gas, this water gas being in each case made in a generator, or, as it is also sometimes called, a cupola or gasogene.

In the generator-superheater apparatus, which is the type most commonly used, the oil gas required for carburetting is made in the presence of the water gas in one or more vessels connected directly to the generator and lined with fire clay blocks and filled with a checker work of fire brick piled in such a way as to afford channels through which the mixture of oil vapors and water gas passes—not in a direct course, but with frequent changes of direction produced by laying the brick in any course at right angles to those in the courses next to it, and over the spaces left between those in the courses parallel and next but one to it. Two such vessels are usually employed, the first being called the carburetter and the second the superheater. During the "blow" the checker bricks are heated by the combustion in the spaces between them of the producer gas formed in the generator. During the "run" the oil is introduced in the top of the carburetter in the form of a spray, which is rapidly vaporized, and these vapors are picked up by the water gas as it comes into the carburetter from the generator and carried through the checker work in both the carburetter and the superheater, being converted by this exposure to heat into a "fixed" or permanent oil gas, which carburets, that is, gives illuminating power to the water gas.

In the generator-retort type the water-gas generator is entirely separate from the carburetted portion of the apparatus, which consists of a carburetter and one or more retorts. The water gas made in the generator is taken into a relief holder and then passed into the carburetter. This is usually a rectangular iron vessel in which are a number of shallow pans set on a slight incline. These pans are fastened on one end and both sides to the shell of the carburetter, an open space being left at the other end, and each pan is inclined in the contrary direction to, and has the open space opposite the closed ends of, the pans immediately above and below it. Under each pan is a steam coil. The naphtha used for carburetting is introduced at the top of the carburetter, falls on the first pan, flows down it and overflows from the open end on to the pan next below, and so on, being vaporized by the heat given out by the steam coils. The water gas, also introduced at the top, travels back and forth over the pans, picking up the naphtha vapor, and passes out at the bottom charged with this vapor. The temperature in the carburetter must be maintained at a point sufficiently high to vaporize all the naphtha before it reaches the bottom. The mixture of water gas and naphtha vapor passes from the carburetter into externally heated "through" retorts similar, in construction and the arrangements by which they are heated, to coal gas retorts, and in passing through these retorts the vapors are converted by exposure to heat into a permanent oil gas.

When heavy oil is used for carburetting the water gas the carburetter is omitted, since it would be impossible to maintain it at a temperature sufficiently high to vaporize such oil, and the oil is introduced directly in the retort, usually passing first into a pipe that carries it from the gas outlet end of the retort almost to the inlet end. In its passage through this pipe it is vaporized and the vapors issuing from the open end mix with the water gas and travel back through the retort, being converted by the heat into a permanent gas. Heavy oil cannot, however, be used to the best advantage in this form of apparatus, which was especially designed for the use of naphtha.

93. Describe the construction of a double superheater Lowe carburetted water-gas apparatus, illustrating the description with a sketch showing a vertical section of the apparatus.


Stack Valve open during Blow, closed during run.
C.
Take-off to Washbox
Oil Nozzle.
B.
Blast Opening
Top Steam.
A.
Water Cooled Valves interlocked so that the top is open when the bottom is closed and vice versa.
Blast Opening
Bottom Steam.
Blast Opening

DOUBLE SUPERHEATER LOWE CARBURETTED WATER-GAS APPARATUS.
VERTICAL SECTION.

Ans. As is shown on the cut, the double superheater Lowe carburetted water-gas apparatus is composed of three cylindrical vessels connected together in sequence. The shells of these vessels are made of wrought iron or steel plates and they are lined with fire clay blocks. An annular space from 1 inch to 1½ inches wide is left between the lining and the iron shell, and is filled with asbestos fibre or other fireproof non-conducting material, to diminish the radiation of heat from the shell.

The first vessel, A, is called the generator; the second, B, the carburetter or first superheater, and the third, C, the superheater, main superheater or fixing chamber.

The generator contains the fuel for heating up the apparatus and producing the water gas, and is provided with a grate and cleaning and clinkering doors, at the grate level, and a charging door or doors on the top. It is usually connected from both the top and the bottom to the top of the carburetter, the pipe leading from the bottom, below the grate, running into that making the straight connection between the tops of the two vessels, as shown on the section. There is a valve in each connection, that in the top being cooled by having water circulating through it. The stems of these valves are connected to each other in such a way that when one is open the other must be closed. The object of this double connection between the generator and the carburetter is to make it possible to pass steam through the fire in the generator either from the bottom up or from the top down. During the "blows" (as the periods spent in heating up the apparatus by means of the air blast are called) the top valve is always open and the bottom one shut, while during the "runs" (as the gas making periods are called) either valve is left open, depending upon the desire to make either an up—or a down—run.

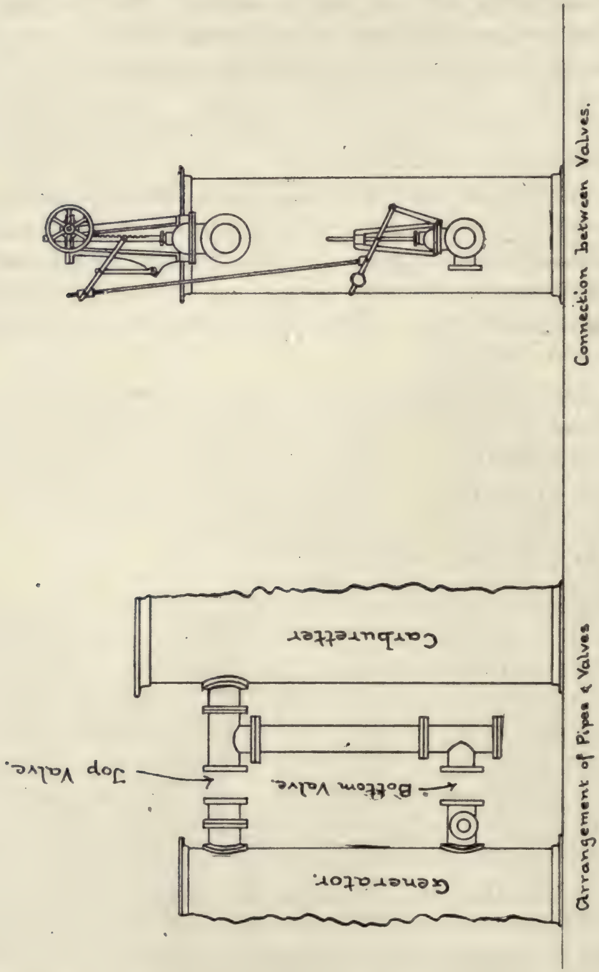
All the pipes connecting the different vessels are lined with fire clay tiles.

The carburetter is filled with a checker work of fire brick on edge, set with from 1½ in. to 2 in. clear space between the rows, and so that the rows break joint with each other. It is connected at the bottom to the superheater or fixing chamber, which is also filled with checker brick. On the top of the superheater is a take-off casting, the top of which opens to the atmosphere and the side to a pipe leading to a small cylindrical vessel called the washbox, which contains water in which the open end of the take-off pipe is sealed. The opening to the atmosphere can be closed by lowering a heavy iron lid, called the stack valve, which by its own weight forms a gas-tight joint with the face of the casting. When this lid is lowered, the only outlet from the superheater is through the take-off pipe and the washbox.

The generator has suitable air blast and steam connections, the carburetter air blast and oil connections, and the superheater air blast connections as shown on the cut. Large openings are provided in the sides of the carburetter and superheater through which the checker brick can be removed and replaced when necessary.

94. Give a description, illustrated with sketches, of some arrangement of valves by means of which steam can be passed through the fire in the generator of a carburetted water-gas apparatus, either from the bottom up or from the top down, as desired, and explain the advantage of being able to so reverse the direction of travel of the steam.

Ans. One arrangement of valves to enable the steam to be passed either upwards or downwards through the fire in the generator of a carburetted water-gas apparatus is illustrated on the accompanying cut. It consists of two valves, one in a horizontal pipe leading directly across from an opening in the side of the generator near its top to a corresponding opening in the side of the carburetter, and the other in the horizontal portion of a pipe leading from an opening in the side of the generator below the level of the grate bars to a connection with the upper pipe between the first valve and the carburetter. These valves are set vertically one above the other, and their stems are so connected by a system of levers and connecting rods, as shown, that one must be closed when the other is open, and vice versa. The upper valve is always open during the blow, and its seat, which is thus exposed to the heat of the blast gases, is made hollow and is kept cool by passing water through it. The lower valve, which is not exposed to any heat during the blow, is a plain double gate valve. The valves are operated by means of a hand wheel keyed to a shaft, on which is a pinion working in a rack on the stem of the upper valve, which is thus raised and lowered directly, motion being transmitted to the lower valve by means of the system of levers and rods.



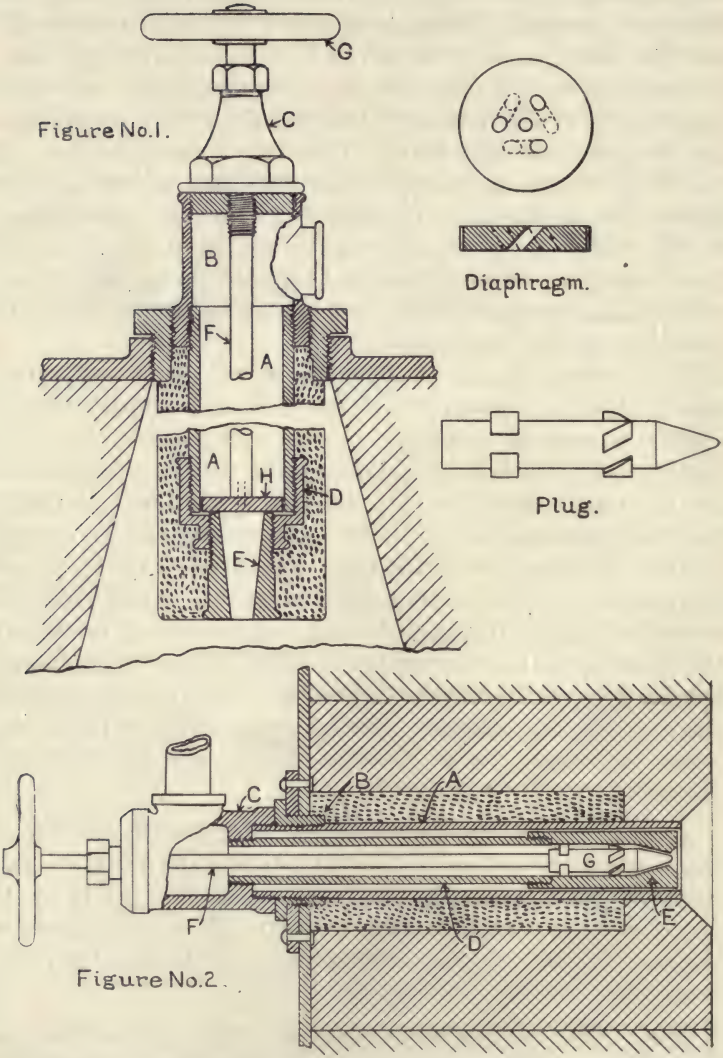
ARRANGEMENT OF VALVES FOR REVERSING THE DIRECTION OF TRAVEL OF THE STEAM IN THE GENERATOR OF A CARBURETTED WATER-GAS APPARATUS.

A steam pipe enters the generator above the top of the fuel bed and one also enters it below the grate bars, each pipe being provided with its own valve. When it is desired to make an "up-run," that is, to pass the steam upwards through the fire, the gas valves are left as they were during the blow, the upper one being open and the lower one closed, and steam is admitted to the generator through the bottom steam pipe. As the only exit open is that at the top of the generator, the steam and the gas produced from it must pass up through the fire and out at the top. To make a "down-run," the position of the valves is reversed, the upper one being closed and the lower one open, steam is admitted through the top steam pipe, passes down through the fire, and the gas produced leaves the generator by the lower opening.

The reversal of the direction in which the steam travels through the fire results in an increase in the capacity of the apparatus, and in economy in fuel consumption. By the passing over it, during the down-run of the hot gas produced in the upper part of the fire, the coal in the lower part, that has been quenched by the steam during the up-run, is reheated so that the blast can rekindle it and bring it to the proper temperature for the decomposition of steam. In this way the accumulation on the grate bars of unburnt fuel is prevented, the result being that a deeper bed of active carbon is maintained, the fire does not have to be cleaned so often, and when cleaned there is less unconsumed fuel taken out with the ashes than when the steam travels through the fire only in the upward direction.

95. Give a description, illustrated with sketches, of one or more forms of oil nozzle for introducing the oil into a carburetted water-gas apparatus, and state the points to be observed in the design of such a nozzle, and the conditions of pressure in the oil pipe and adjustment of the opening in the nozzle that give the best results.

Ans. The oil nozzle or spraying device illustrated by Figure No. 1 on the accompanying cut is one that is extensively used on double superheater carburetted water-gas sets. It is mounted on the top plate of the carburetter neck and delivers the oil downward.



OIL SPRAYS FOR CARBURETTED WATER-GAS APPARATUS.

According to the patent specifications its principal features are "a sectional casing, a diaphragm provided with inclined openings for imparting rotary motion to the jets or streams of liquid hydrocarbon as they are discharged from the casing, and means for adjustably seating said diaphragm."

The casing is formed of a cast iron tube, A, with an external thread at each end, a cast iron tee, B, screwed on the upper end of the tube, a stuffing box, C, screwed into the upper opening of the tee, a reducing coupling, D, screwed on the lower end of the tube, and a nozzle, E, screwed into this coupling.

Through the stuffing box passes a steel spindle, F, which works in a thread cut in the bottom of the box in the same manner as an ordinary valve stem. On the upper end of this spindle is fastened a small handwheel, G, by which it can be easily turned and thus raised or lowered. To the lower end is fastened the diaphragm, H. This diaphragm is faced so as to make a tight joint with the upper edge of the nozzle, E, this edge being also faced and made to project above the bottom of the coupling so as to form a seat for the diaphragm. In the latter are drilled holes inclined at an angle to its face as shown in the enlarged plan and section of it given on the cut. The number and size of these holes are varied to suit the size of the set on which the nozzle is to be used, since the quantity of oil that has to be passed in a given time depends upon the rate at which gas is made, that is upon the size of the set. The lengths of the tube A and the spindle F are also made to suit the length of the carburetter neck, the bottom of the nozzle being brought either just even with or a trifle below the level of the carburetter head.

After being put together the spraying device is fastened to the plate covering the neck of the carburetter by means of a bushing. The parts exposed to the heat inside the carburetter are protected by being wrapped with asbestos wick.

The oil supply pipe is connected to the side outlet of the tee, B.

When oil under pressure is supplied to this device with the diaphragm pressed tightly down upon the nozzle, it can pass only through the inclined openings in the diaphragm. It issues from these at a high velocity, and, striking against the circumference of the nozzle at an angle, is given a rotary motion which causes it to spread out in a spray as it leaves the nozzle and distribute itself over the whole surface of the cross section of the carburetter. The extent to which the spray will spread out is controlled by raising the diaphragm from its seat and thus allowing more or less of the oil to pass around its circumference instead of through the holes. The oil thus passed around, if not in too large quantity, will be broken up and given a rotary motion by the jets coming through the holes, but the doing of this work will absorb some of the energy possessed by the jets and will thus reduce the velocity of rotation of the oil and therefore the extent to which the spray will spread.

Another form of spray which is used on carburetted water-gas apparatus of a different make from that using the form described above is illustrated by Figure No. 2 on the cut. It is mounted on the side of the carburetter or superheater and delivers the oil horizontally.

This form differs from the one previously described principally in the use of a plug instead of a diaphragm for giving the oil a rotary motion.

The outer casing tube, A, is made of wrought iron pipe and is threaded externally at one end only. Over this end is screwed a bushing, B, run far enough down to leave sufficient thread to allow the recessed end of a tee, C, to be screwed on the tube. In a smaller thread at the same end of the tee is screwed the outer end of the inner tube, D, which tube is threaded externally at both ends. On its inner end is screwed a steel nozzle, E. The tee, C, is provided with a stuffing box through which passes a spindle, F, similar to the one described above.

To the inner end of the spindle is fastened a plug, G, an enlarged view of which is also shown on the cut. It is made with a cylindrical body, with one end cut off square and the other made conical, and is provided with two sets of lugs which serve to break up the oil and give it a rotary motion.

The conical end of this plug fits against a conical seat in the nozzle and thus serves as a valve by which the flow of oil can be controlled. The lugs nearest the square end of the plug have their longitudinal edges parallel to the axis of the plug, while those nearest the conical end have their edges at an angle with the axis and are so placed around the circumference that the ends toward the first set come opposite the openings between the lugs of that set. Both sets of lugs fit closely against the circumference of the recess in the nozzle so that all the oil has to pass through the spaces left between the lugs themselves.

The operation of the device is similar to that of the one first described. When oil is to be introduced into the apparatus the plug is drawn off the seat in the nozzle far enough to permit the oil to pass at the required rate. Oil is then forced under pressure through the inner tube until it strikes the lugs, and in passing between them is first broken up and then deflected so that it strikes against the conical portion of the nozzle at an angle, and is thus given a rotary motion which causes it to form a spreading spray as it issues from the nozzle orifice.

The main points to be observed in the design of an oil nozzle to be used for introducing oil into a carburetted water-gas apparatus are that it shall produce a good spray the spread of which is under control, that the parts that produce the spray shall be kept as much away from exposure to heat as possible, and that these parts shall be so constructed that they will continue to work well even if they become slightly warped under the influence of the heat. The design should also be such that the nozzle can be readily withdrawn and new parts substituted for any that may become injured or worn out. Operators vary in their ideas as to the proper pressure to be used even with the same nozzle, but twenty pounds per square inch may be taken as a good pressure, and the opening between the diaphragm or the plug and its seat should be such that the nozzle will pass the required amount of oil with this pressure and at the same time produce a spray that will spread so as to cover the full cross section of the carburetter before it reaches the top of the checker brick.

96. Should the lining in the generator of a carburetted water-gas apparatus be made single or double? Give the reasons for your answer.

Ans. The lining for the generator of a carburetted water-gas apparatus can be made of single courses of blocks having the desired thickness, except for that portion of the height extending from just below the level of the grate bars to a point 4 ft. above these bars, or even 5 ft. above, if the fuel used is such that clinker forms against the wall to an unusual height, where it should be made with inner and outer courses whose combined thickness, including that of the joint between them, is equal to that of the single courses used above and below this zone.

Except at the place mentioned the lining is not subject to any considerable wear and should not have to be renewed more than once in four to five years. A single course of thick blocks can be made and put in place more cheaply than two courses of thinner blocks and therefore is to be preferred where the wear and tear is inconsiderable. For a height of 3 ft. or 4 ft. above the grate, however, the inner surface of the lining is subjected to a great deal of wear, on account of the formation, during the operation of the apparatus, of hard clinker which adheres tightly to the wall of this portion of the generator and has to be cut away from it with heavy steel bars each time the fire is cleaned. Even when the greatest care is taken not to injure it, the wall is sure to suffer from this cutting in the course of no great length of time and this part of the lining of the generator must be renewed at intervals of from one to two years. If it is made in a single course of blocks the whole of the lining within the clinker zone must be taken out and replaced at these times, while if made in two courses it is only necessary to renew the inner course. In any case the work must be done before the thickness of the whole lining is reduced to that of the outer course of the two, so that the intervals between renewals cannot be made any longer with a single lining and the extra cost of renewing a single lining as compared with that of renewing only the inner course of a double lining cannot be offset in this way. A double lining for this part of the generator is therefore more economical in the long run even though it may cost slightly more at first.

If, as is sometimes the case, a double lining is used throughout, at least two courses of single lining should be put in immediately above the courses that require frequent renewing in order to hold up the inner courses of the wall above them while the work is under way. If these single courses are not provided it is necessary to support the upper part of the wall when relining, and this adds to the length of time required to do the work of relining as well as to the cost of this work.

97. Describe one, or more, of the various methods of construction that are employed to reduce to a minimum the damage resulting from an explosion in the blast pipe of a carburetted water-gas apparatus, and explain how they act.

Ans. One method for reducing to a minimum the damage resulting from an explosion in the blast pipe of a carburetted water-gas apparatus is to place at different points on the blast pipe relief valves which are loaded so that, while they remain tightly closed as long as the pressure in the blast pipe is at or below normal, they will be raised as soon as the pressure exceeds the normal. It is usual to place one of these relief valves on each of the elbows nearest to the valves governing the admission of the blast to the various parts of the apparatus. If an explosive mixture of air and gas is formed in the blast pipe during the run and exploded when the blow is put on, these valves are at once opened by the increase in pressure and afford a relief, which, if the explosion is not too violent, will prevent injury to the blast pipe or blowers.

The same effect may be secured by having one section of blast pipe made very light so that it will give way and relieve the pressure before any damage is done to the stronger portions of the pipe. Duplicates of this light section are kept in stock and can be put in place very quickly, so that gas making can be resumed in a short time after the explosion.

A third method is to put at every place at which the blast pipe changes its direction a tee with its free end pointing in the direction that would be followed by the explosive wave travelling back from the apparatus towards the blowers. The end of each tee is flanged and closed by a blind flange of tin bolted on with very light bolts. In case of an explosion these thin flanges are blown off before the pressure rises to a point high enough to damage the pipe, especially as they receive the full force of the wave as it travels along.

Another device which prevents the wave from travelling past a definite point in the blast pipe is called an explosion valve. It consists of a box set in and forming part of the blast pipe. This box is divided into two compartments by a partition at right angles to the axis of the blast pipe, and having in it a number of long, narrow, horizontal openings, the spaces between the openings being faced on the side away from the blowers. Flaps made from leather or rubber belting backed with iron to give them weight and stiffness, are fastened by their upper edges on the side of the partition towards the apparatus in the spaces between the openings so that each flap hangs in front of and covers an opening.

A pipe at least as large as the blast pipe leads from the top of the compartment nearest the apparatus to a convenient height above the ground, and its open flanged end is covered with a blind flange made of tin and bolted on by small stove bolts. As long as air is being driven through the pipe the flaps are kept off the partition plate and the air passes through freely, but when an explosion takes place, beginning, as it always does, at the apparatus, the wave travelling back along the pipe throws the flaps against the partition and closes off any communication with the part of the box on the blower side. At the same time the tin flange is blown off the top of the riser pipe and the pressure relieved. Such a valve furnishes an absolute protection against injury to the blowers. It should be located, if possible, just outside the generator house, but can be put inside of this house if necessary.

Various devices are employed to avoid explosions by preventing gas from accumulating in the blast pipe, but these do not come within the scope of the question.

98. Describe, somewhat in detail, the starting of a fire in, and the heating up to a working heat of a carburetted water-gas apparatus of the generator-superheater type; and the putting on, making and taking off of the first run.

Ans. It is assumed that the apparatus has previously been in use and therefore does not require to be dried out, and also that during the time it has been out of use all necessary repairs have been made, so that all of the valves and piping are in good condition. Just before making the fire the pressure gauges and seals should be filled with water, and water should be started running through the water-cooled valve, if the apparatus is fitted for the reversal of steam. If the condenser is already full of water, no water need be turned on it, nor need any be turned on the scrubber until the set has been heated up and is ready to make gas. The superheater stack valve should be open, and the upper valve of the steam reversal attachment should also be open.

A layer of coarse ashes or clinkers from 6 in. to 12 in. deep should be spread over the grate bars to protect them from the overheating and warping that would take place during the long blow if the fire were built directly upon them. (If this is properly and carefully done there will be no danger of the bars becoming overheated, but in any case the bottom door of the generator should be opened after the blast has been on for say fifteen to twenty minutes, and if the fire is found to be too hot on the bars a little steam should be turned on with the blast to cool the lower part of the fire, and so protect the bars from injury.) The stoppers should be placed in the stoke holes and the stoke hole doors closed, the ash-pit doors being left open. If the water-gas apparatus is used in combination with a coal-gas plant the fire can be started by putting into the generator, on top of the layer of clinkers, several barrows of hot coke, followed by a quantity of cold coke, or coal, sufficient to fill the generator half full. If no hot coke is available the fire must be started with wood, enough being used to insure the ignition of the coal or coke, which may either be put on before the wood is lighted, or else put on after the wood fire has gotten well under way. If the first method is employed the coal is put on the wood to a depth of one to two feet, and the wood is ignited from below, the charging lid of the generator being left open until the wood is burning freely, when it is closed, and the products of combustion are drawn through the carburetter and superheater. In this case old oil-soaked waste can be used as a kindling underneath the wood. If the coal is put on after the wood has been lighted no kindling is needed, since the fire can be started by throwing a couple of shovels of hot coal, taken from the boiler fire, on top of the wood. When the wood is burning briskly the coal can be charged to the proper depth and the charging lid closed.

In either case, when the wood has burnt out, leaving the coal well ignited, the generator lid should be opened, a torch being used as in regular running to avoid an explosion, the generator half filled with coal, the lid closed and screwed down, the ash-pit doors closed and sealed up, and the generator blast valve opened, the blower having been previously started. After blasting for a sufficient length of time (say 20 to 30 minutes) to have the coal and upper part of the generator well heated and have the blast gas passing into the carburetter hot, the carburetter blast valve can be opened slightly, using an iron rod with its end heated to a bright red and put through the sight hole to ignite the gas as it meets the air. If the gas is hot enough, it will, when once ignited, continue to burn after the rod is withdrawn, and a blue flame will be visible through the sight hole, but if the gas is too cold the flame will go out when the rod is removed, and the blast must be shut off, to be turned on again later and a second attempt at ignition made.

When the carburetter shows a fair heat, as it will in about thirty minutes after the blast has been turned on to it, the superheater blast can be turned on, the ignition of the gas being effected by a rod heated at the end and inserted through the lower sight hole, the presence or absence of a blue flame after the rod is withdrawn indicating, as in the case of the carburetter, whether the blast can be left on or must be turned off until a higher temperature is reached.

The superheater having been successfully lighted, the blasting is continued until the carburetter and superheater are heated up to nearly the right temperature for gas making, the blast being so adjusted that all the combustible portion of the blast gas is consumed without having any excess of air on the superheater, and the generator being coaled when necessary. The total time required to bring the apparatus to this point after the blast is first turned on will be from 1½ to 2 hours. When it is reached the blast should be shut off, the generator filled with coal and the blasting resumed for from five to ten minutes more, to get the heats to the gas-making point.

When this is reached the blast valves are shut, beginning at the superheater and finishing at the generator, the steam is turned on, the stack valve closed, and, finally, the oil pump started and the oil admitted to the carburetter. Before turning on the oil for this first run the pressure gauges should be looked at to see if the proper pressure is shown, and so make certain that everything is tight and that there are no large leaks that need to be stopped before gas making can be carried on. During the run the rate at which the oil is being fed into the apparatus must be watched and so regulated that the desired quantity is used. One minute before the end of the run the oil should be shut off in order to avoid loss of oil gas when the run is taken off. At the end of the time allowed for the run the steam is shut off, the stack valve opened, the blast turned on the generator, carburetter and superheater, in the order named, and the apparatus heated up for another run.

99. Describe the operation of a carburetted water-gas apparatus of the generator-superheater type during its regular working, including in the description an account of how to handle the various blast valves so as to bring the different parts of the apparatus to the proper temperatures simultaneously and without any waste of fuel.

Ans. In the normal operation of a carburetted water-gas apparatus the work is usually arranged so that the fire is cleaned early in the working day, and the description of the method of operation will be begun with this cleaning.

After the last run is taken off, the apparatus should be blown through with only the generator blast valve open for, say, 20 seconds, to free the space below the fire from any water gas, the blast valve should be closed, leaving the stack valve open, the blower shut down, unless two sets are being worked in conjunction, an examination made to see that all steam is turned off from the set, and then the ash pit and stoke hole doors should be opened and the plugs removed. Working through the stoke holes with the proper tools (hooks and hoes) all the ashes and soft clinker should be loosened up and removed from around the outside of the fire, leaving the centre undisturbed until the work around the sides has been completed. After cleaning out all the clinker that is sufficiently loose and soft to be worked out with the hooks, as much of the hard clinker as possible should be cut away from the walls with chisel bars, with a slight bend to enable them to reach the proper points, the lumps cut off being removed from the grate with the hooks. It may be necessary to use a sledge on the bars to loosen the clinker if it is very hard, care being taken not to knock down the fire. When all that can be done around the outside without dropping the fire has been done, the ashes and clinker should be cleaned out from the centre and the fire dropped on the grate in a solid mass, no large spaces being left unfilled. The centre of the fire is left until the last because, as a rule, the clinker here is softest and the fire is apt to drop and interfere with the work as soon as this portion is disturbed, while it will hold up much better on the sides, and even if it should happen to come down there before the centre is cleaned the soft clinker can be broken up with chisel bars and all the ashes raked out by working between the grate bars with a long hook. The bottom cleaning having been completed and the ashes removed from the ash pit, the ash pit and stoke-hole doors should be closed tight, the charging door opened and the fire barred down from the top to cut off from the side of the generator any clinker situated too high up to be reached from the bottom with the bent bars. This barring down is done with long chisel bars of different sizes, varying from light ones, which can be handled by one man, for use when the clinker is soft, to heavy ones for hard clinker which require three or four men to work them. If the clinker is very hard it may be necessary to drive the bars with sledges until the holes so made have weakened the clinker sufficiently to allow of its being broken down by the hand bars. In all work with bars care must be taken to keep the bars away from the brickwork, two or three inches of clinker being left on the face of the bricks as a protection against wear and tear. The length of time required for cleaning will vary according to the condition of the fire, but will not usually be more than an hour.

The cleaning having been finished the generator should be filled with fuel and the full blast turned on. It will probably be necessary to make several blows and runs before the fire becomes heated through and during these blows the generator blast valve must be kept full open. But when the fire is in good shape the valves on the different parts of the apparatus should be so adjusted as to bring all to the proper temperature simultaneously and without any waste of fuel. The adjustment required for the accomplishment of this object will vary with the condition of the fire and the character of the generator fuel and carburetting material used, and the conditions must be studied for each case. The goal to be worked for is the bringing of the generator up to heat without making any more producer gas than is required to raise the checker work in the carburetter and superheater to the proper temperature for the gasification of the oil. The smaller the amount of combustible gas formed in the generator during the blow the smaller will be the amount of fuel used per 1,000 cu. ft. of gas made, and, therefore, no greater quantity of such gas should be produced than is needed for the heating of the carburetter and superheater. In one case it may be found that the most economical fuel results are obtained when the generator blast valve is not fully opened, in others it may be necessary to have it opened wide. Experiments must be tried with each set of apparatus to determine just how the valves shall be handled so as to avoid, as far as possible, the escape of unconsumed carbon monoxide, as shown by the presence of a blue flame at the superheater stack, and have all parts of the apparatus heated up within the usual time allowed for a blow, say 6 to 7 minutes. When the apparatus is properly heated the same adjustment of valves will give the desired result for each blow as long as the amount of carburetting material used per 1,000 cu. ft. and the amount of gas made per run are not varied to any great extent.

As the operation of putting on and taking off a run was described in the answer to question No. 98, it is not necessary to repeat it here. After every four or five runs fresh fuel should be put in the generator to keep the height of the fire as nearly uniform as possible.

100. Give a description, illustrated with a sketch showing a vertical section of the apparatus, of the construction of a double superheater Lowe carburetted water-gas apparatus, and give a brief description of its operation for the manufacture of carburetted water gas.

Ans. As is shown on the cut on page 171, the double superheater Lowe carburetted water-gas apparatus is composed of three cylindrical vessels connected together in sequence. The shells of these vessels are made of wrought iron and they are lined with fire clay blocks. An annular space from 1 in. to 1½ in. wide is left between the lining and the iron shell, and is filled with asbestos fibre or other fireproof non-conducting material, to diminish the radiation of heat from the shell.

The first vessel, A, is called the generator; the second, B, the carburetter or first superheater, and the third, C, the superheater, main superheater or fixing chamber.

The generator contains the fuel for heating up the apparatus and producing the water gas, and is provided with a grate and cleaning and clinkering doors at the grate level, and a charging door or doors on the top. It is usually connected from both the top and bottom to the top of the carburetter.

The carburetter is filled with a checker work of fire brick on edge, set with from 1½ in. to 2 in. clear space between the rows, and so that the rows break joint with each other. It is connected at the bottom to the superheater or fixing chamber, which is also filled with checker brick. On the top of the superheater is a take-off casting, the top of which opens to the atmosphere and the side to a pipe leading to a small cylindrical vessel called the wash-box, which contains water in which the open end of the take-off pipe is sealed. The opening to the atmosphere can be closed by lowering a heavy iron lid called the stack valve, which by its own weight forms a gas-tight joint with the face of the casting. When this lid is lowered the only outlet from the superheater is through the take-off pipe and the wash-box.

The generator has suitable air blast and steam connections, the carburetter air blast and oil connections, and the superheater air blast connections as shown on the cut. The operation of the apparatus is as follows:

A fire is started in the generator A, and this vessel is filled with coke or anthracite coal which is brought to a high temperature by the air blast. Owing to the depth of the fuel bed and the comparatively limited amount of air admitted to the generator, the combustion of the fuel is not perfect and the products of combustion passing off through the carburetter to the superheater contain carbon monoxide. By blowing air into the carburetter and superheater this carbon monoxide is consumed in these vessels and the checker work, with which they are filled, is highly heated. The products of the final perfect combustion so obtained pass off through the open stack valve to the stack and the atmosphere. This blowing up is continued until all parts of the apparatus have been brought to the proper temperature. The blast is then shut off and the stack valve closed. Steam is admitted through the steam pipe to either the top or the bottom of the generator, as the case may be, and passing through the fuel bed is decomposed by the hot carbon, its oxygen uniting with the carbon to form carbon monoxide, while the hydrogen is set free. The mixture of hydrogen and carbon monoxide, called water gas, passes over into the carburetter through the top of which oil is admitted. The oil being vaporized by the heat, the vapors are picked up by the water gas and pass forward with it over the hot checker brick in the carburetter and superheater. The long continued exposure to heat converts the oil vapors into permanent oil gas, this oil gas being mixed, during its formation, with the water gas and the result is an illuminating gas, which, properly speaking, should be called carburetted water-gas, but is commonly known as water gas. The stack valve being closed, this gas passes out of the superheater by way of the take-off pipe and wash-box, from which it goes to the scrubber and the rest of the apparatus.

The decomposition of the steam absorbs heat from the fuel in the generator and the distillation of the oil takes up heat from the checker brick in the carburetter and superheater, so the apparatus gradually cools down during the periods of gas making. When it has been cooled to a temperature at which gas cannot be economically produced, the oil and steam are shut off, the stack valve opened, the blast turned on and the heating up process repeated. The operation thus consists of a series of alternating periods of heating up called "blows," and periods of making gas called "runs."

101. In a water-gas apparatus, of the Lowe type, what influence does the character of the fuel used have upon the depth of fire and the amount of air blown into the generator?

Ans. A porous fuel, such as coke, requires a deeper fuel bed than a dense fuel, such as anthracite. The amount of air blown into the generator will be practically the same per pound of combustible used, whether the fuel were coke or anthracite. The amount of air per pound of combustible would vary with the amount of hydrogen in the fuel. Ignoring the hydrogen, which is present in very small proportions in coke and anthracite, the amount of air blown into the generator would be the same per pound of combustible, whether coke or anthracite, if the conversion of the oxygen of the air into carbon dioxide and into carbon monoxide, and the escape of uncombined oxygen, from the top of the fuel bed, were in the same proportion.

102. It is found by test at a certain gas works that when using anthracite coal in the generator of the carburetted water-gas apparatus the generator fuel amounts to 34 pounds per 1,000 cubic feet of carburetted gas made and the rate of make

is 13,000 cubic feet per hour; while when a certain furnace coke is used the generator fuel amounts to 37 pounds per 1,000 cubic feet and the rate of make is only 9,000 cubic feet per hour. The price of coal is $4.90 per gross ton and the wages of the gas maker are 20 cents per hour. What would be the equivalent price per gross ton of the coke, all items affecting the cost of the gas which are not mentioned above being considered equal in the two cases?

Ans. Since, as stated in the question, the items of generator fuel and gas maker's labor are the only ones to be considered, the price of coke equivalent to a price of $4.90 per gross ton for anthracite coal must be such that the total cost of gas maker's labor and generator fuel per 1,000 cubic feet of gas made will be the same in each case.

In the case of the coal, under the conditions stated in the question, 34 pounds costing $\frac{490}{2240} = 0.219$ cent per pound, are required for generator fuel per 1,000 cubic feet of gas made, so the cost of this fuel will be $34 \times 0.219 = 7.45$ cents per 1,000 cubic feet. The cost of gas maker's labor is 20 cents per 13,000 cubic feet or $\frac{20}{13} = 1.54$ cents per 1,000 cubic feet. The total cost for generator fuel and gas maker's labor is therefore 8.99 cents per 1,000 cubic feet.

When using coke the gas maker's labor will cost 20 cents per 9,000 cubic feet, or 2.22 cents per 1,000 cubic feet. The price at which coke must be bought to be equivalent to coal at $4.90 per ton is therefore $8.99 - 2.22 = 6.77$ cents for the amount, 37 pounds, required as generator fuel per 1,000 cubic feet of gas made. This is equal to a price per pound of $\frac{6.77}{37} = 0.183$ cent, or a price per gross ton of $4.10.

103. When using gas oil as the carburetting material in a double superheater carburetted water-gas apparatus, should the checker bricks be kept at the same temperature in both the carburetter and superheater? If not, in which vessel should the highest heat be carried? Give the reasons for your answer.

Ans. Under ordinary conditions, the best oil efficiencies are obtained by carrying the checker bricks in the carburetter at a higher heat than those in the superheater.

The reason for this is that a high initial heat seems to be required for evaporating the oil and breaking it up into permanent gases, while these gases, after their formation, should pass as soon as possible into a somewhat lower temperature, since the heavy hydrocarbons or illuminants will be deteriorated by further breaking down if they are subjected to too long an exposure to the high temperatures at which the oil is best broken up.

104. In the manufacture of carburetted water-gas it is customary to have the water gas pick up the oil, in a state of vapor, at the entrance to the fixing vessels and carry this vapor and the resulting gas through these vessels, the oil gas being thus made in the presence of the water gas. What advantages has this method over that of making the oil gas entirely separate from the water gas?

Ans. The principal advantage that is thought to be obtained by carrying on the manufacture of carburetted water-gas so that the oil gas portion is made in the presence of the water gas instead of being made entirely separate from the water gas, is that the presence of the water gas shields the oil gas from the heat and renders it less subject to over-decomposition in case the temperature of the heated surfaces is too high or the exposure to the heat too prolonged. The effect upon the oil vapors and gas of exposure to heat of too great intensity or for too long a time is to produce either hydrocarbon gases of low illuminating values, or hydrocarbon vapors which, although they are of high illuminating value, can be carried by the gas only to a limited extent. By separating and surrounding the molecules of the oil vapors and gas, the water gas reduces the extent to which they are exposed to the heat and so reduces the liability to over-decomposition.

On the other hand, it is possible that an excess of water gas will exert so great an effect as to interfere with the complete gasification of the oil, and in cases where the amount of exposure is small or the intensity of the heat low, the presence of water gas during the decomposition of the oil may be detrimental. This, however, will not occur in an apparatus that is properly designed and handled.

Another advantage of making the oil gas in the presence of the water gas is that the latter will pick up and carry oil vapors that escape gasification, and, if the water gas were not present, would be condensed and left behind when the oil gas was cooled. These vapors are of value as illuminants, and so the candle power of the carburetted water-gas made in this way will be higher for an equal amount of oil used than will be that of carburetted water-gas made by making the water gas and oil gas separately and mixing them cold. This advantage can, however, be obtained to a great extent even when the two gases are made separately by mixing them hot.

This method of making carburetted water-gas also makes it possible to conveniently arrange the apparatus so that the heat required for the gasification of the oil can be furnished very economically by the combustion, and partly by the sensible heat, of the producer gas formed in the generator while the fuel is being heated up to the temperature required for the manufacture of water gas.

105. What are the advantages derived from heating the oil used in a carburetted water-gas apparatus before it is admitted to the carburetter?

Ans. The advantages derived from heating the oil used in a carburetted water-gas apparatus before it is admitted to the carburetter are a saving in coal, if the oil is heated by heat that would otherwise be wasted, and an increased efficiency in the use of oil.

All the oil run into the carburetter must be raised from the temperature at which it enters, to that existing in the carburetter, by means of heat supplied from the checker-brick, after having been received by them from the blast gases during the preceding blow. The lower the temperature at which the oil enters, the greater the quantity of heat that must be given out by and supplied to the checker-brick, and, therefore, the greater the quantity of combustible blast gases required to be produced and the greater the consumption of coal in the generator. Any heating of the oil before it enters the carburetter thus causes a corresponding decrease in the amount of coal used in the generator and if the otherwise waste heat in the gas leaving the apparatus is utilized for the purpose the result is a clear gain in economy of fuel.

The work of heating, vaporizing and gasifying the oil lowers the temperature of the checker-brick in the carburetter and superheater continuously from the beginning to the end of a "run," and this cooling effect is naturally greatest at the top of the carburetter where nearly all of the heating and evaporating of the oil is done. It is evident that, to obtain the best results, the temperature of the checker-brick should be kept throughout the run, as nearly as possible, constant and at the point best suited to the oil being used, and that any variation of the temperature from this point means a change in the conditions under which, and, consequently, probably a change in the efficiency with which, the oil is being gasified. Preheating the oil lessens this variation in temperature and therefore enables the oil to be gasified more efficiently. It would seem that when the oil is heated to a high temperature, the checker-brick in the carburetter and superheater should be kept at a lower temperature than when cold oil is used, in order to prevent the overheating and excessive breaking down of the heavy hydrocarbons derived from the oil.

It should be noted, however, that, on account of its partial vaporization, oil when heated to a high temperature is harder to spray evenly into the carburetter and that, consequently, some engineers prefer to use the oil without preheating it.

106. How do you determine when the checker bricks in a carburetted water-gas apparatus need cleaning?

Ans. The checker bricks of a carburetted water-gas apparatus should be removed and cleaned, or renewed, when dirty or crushed, or disintegrated. Checker bricks may become covered with a non-conducting coating of ashes or carbon, or both, making impossible the desired exposure of the oil vapors to properly heated brick surfaces. When bricks are coated or saturated with carbon the surface heats rapidly, because the carbon burns, and the gas maker is deceived by the glowing carbon and believes the bricks to be hotter than they are. It is possible to tell something of the condition of the checker bricks by observation through the sight cocks provided for the purpose. Other indications of dirty bricks are a falling off in the rate of make per minute and in the oil results. If all the conditions of operating remain unchanged, and the candle power falls materially and stays down and the make of gas per minute of run is reduced, the checker bricks should be at once examined and, if dirty, cleaned and removed. Bricks should not be allowed to become so fouled as to make a material reduction in the rate of make. Experience soon teaches an intelligent gas maker to avoid both the extreme of reduced results and of too frequent cleaning.

It is the custom in many works, especially those that are provided with a spare set of apparatus, to change the checker brick at regular intervals, these intervals being measured in some cases by the number of days that the set has been in operation, and in others by the number of hours of work actually done. The object of changing the bricks at fixed intervals in this way is to avoid the irregularities in make and working results that arise from running until it is absolutely necessary to make the change, it being thought that the loss due to a day or two of poor working is greater than the slight extra cost involved in cleaning the bricks a little oftener.

In a works that has only one set of apparatus, the bricks should be put in good shape as late as possible in the fall so that they will be in good condition during the heavy make of December and January.

107. Describe the cleaning of the washbox of a carburetted water-gas apparatus, including the precautions to be observed to prevent the occurrence of any accident.

Ans. There are two arrangements of washbox in water-gas apparatus. In one the take-off from the washbox is on top, and in the other it is on the side and connects directly with the scrubber.

The connection from the gas outlet on top of the superheater to the washbox varies in different forms of water-gas apparatus. In most cases there is a lid on top of what is known as the oil heater connection, which can be opened to clean the oil heater.

When no oil heater is used, the take-off connection from the superheater has a handhole cross at the top of the superheater, connecting the vertical riser from the washbox to the outlet branch on the superheater.

When the washbox has a take-off on top, there is a valve between the washbox and the scrubber which can be closed, and will thus shut off communication between the washbox and the scrubber. In this case, first open either the lid on top of the oil heater, or, in case there is no oil heater, the handhole on the cross; then shut off the overflow from the washbox to the seal pot, open the handhole on top of the washbox and fill the washbox with water. When the washbox has been filled, draw off the water, open the handhole or manhole on the side of washbox and remove the tar, etc.

In case the washbox is joined to the scrubber by a side outlet, and there is no valve between them, the gas valve at the outlet of the scrubber must be closed. The stop cock on the overflow pipe from the scrubber must now be shut and the manholes on the scrubber opened, beginning with the one on top and working downward. The openings on the take-off pipe from the superheater to the washbox and the handhole on top of the latter must also be opened up, and the washbox filled with water until this rises into the standpipe above the top of the box. This, of course, involves filling the scrubber also to an equal height. Before emptying the washbox the standpipe should be thoroughly cleaned of all carbon and tar to remove all danger of its catching fire and igniting any gas that might work back from the scrubber when the water is run out. If any of the carbon should happen to be on fire when it is scraped down it will be extinguished by falling into the water, and before the water is drawn off care must be taken to see that none remains unextinguished. After the standpipe has been cleaned it should be plugged, just below the connection to the superheater, with either a bag of wet sawdust or a board cut to fit it fairly tight and plastered around the edge with fire clay to close all cracks. The object of this plugging is to prevent any gas that may work back from the scrubber from being ignited at the top of the superheater. The water can now be run off the washbox and scrubber and the washbox opened and cleaned.

The differences between the two methods are called for by the necessity of seeing that the scrubber is thoroughly ventilated when it cannot be shut off, and of taking precautions to prevent the ignition of any gas that may still remain in the scrubber in spite of the ventilation given it. *In any case the washbox and its connections must be thoroughly ventilated, and it should be provided that no fire comes near the washbox or its connections, or the scrubber, while they are open, and that no light is used about the work.*

108. The dip pipe on the take-off from the superheater into the washbox of a double superheater carburetted water-gas apparatus has an internal diameter of 10 in. and an external diameter of 11¼ in. and has a seal of 2 in. The internal diameter of the washbox is 4 ft. 0 in. The drain pipes from the scrubber and condenser are carried down below the surface of the liquor in the seal pot to a depth of 3 ft. 9 in. Two sets are in operation. An obstruction occurs in the pipe taking the gas from the condensers while one set is making gas and the other is under blast. Will the gas show first at the scrubber and condenser seals or at the top of the superheater of the latter set? Give the reasoning and calculations by which your answer is reached.

Ans. The gas will show first at the opening through which it can pass with the least resistance, and it is therefore necessary to determine the resistance offered by the washbox to the backward passage of gas and compare it with that offered by the depth of seal on the drain pipes.

Before any gas can pass backward through the washbox, the level of the water in the portion outside of the dip pipe must be depressed below the lower edge of this pipe, the water displaced being forced into the dip pipe. The pressure required to depress the level outside and raise that inside will be equal to the height, above the lower edge of the dip pipe, to which the water will have risen in the dip and take-off pipe when the outside level is just even with this edge. This height will be equal to the height at which the water, on the inside, stands above the edge when the pressures are equal inside and out, plus the quotient obtained by dividing by the area of the pipe the volume of water that has to be forced from the outside to the inside. The above volume of water is equal to the area of the space in the washbox outside the dip pipe multiplied by the depth of the seal.

In the case given, as the diameter of the washbox is 4 ft. 0 in. or 48 in., and its area is 1809.6 square inches, while the outside diameter of the dip pipe is $11\frac{1}{4}$ in. and its area is 99.4 square inches, the area of the space outside the pipe is $1809.6 - 99.4 = 1710.2$ square inches. The depth of seal is 2 in. and therefore the volume of water to be displaced is $1710.2 \times 2 = 3420.4$ cubic inches. The internal diameter of the dip pipe is 10 in. and the internal area 78.54 square inches, hence the displaced water will fill the dip pipe to a height of $\frac{3420.4}{78.54} = 43.5$ in. The dip pipe being sealed to a depth of 2 in., the water will stand in it to that height when the pressures inside and outside are equal, and, therefore, the total height to which the water will have to be raised on the inside, before the bottom edge of the pipe will be left uncovered on the outside, will be $43.5 + 2 = 45.5$ in.

Since the drain pipes from the condenser and scrubber are sealed to a depth of 3 ft. 9 in., or 45 in. only, gas will escape through them before it shows at the top of the superheater, and will escape through the latter opening only in case the blowing of the seal on the drain pipes does not afford sufficient relief to keep the pressure down to 45 in.

Scrubbing.

109. In the manufacture of carburetted water-gas it is found that with the use of ordinary methods of condensing and tar extracting some vapors remain in the gas until the purifiers are reached, and are then deposited in the purifying material, with the effect of shortening its life. What has been found to be an efficient way of removing these vapors before the purifiers are reached?

Ans. The method which has been finally settled upon, after much experiment, as being the most efficient in removing those vapors which still remain in carburetted water-gas after it has passed through the ordinary condensing and scrubbing apparatus, but which if not removed would be absorbed by and clog the purifying material, is to pass the gas through a layer, or layers, of planer chips before it comes in contact with the purifying material. This may be done in the simplest manner by putting a layer of the chips on the lower tier of trays in each purifying box, so that when a box becomes the first in the series the gas passes through this layer of chips and the vapors are strained out before the purifying material is reached. But this method, though simple, is more expensive in operation and not as efficient as the one adopted at several works where the planer chips are used in deep layers in separate vessels of the same form as the ordinary tower scrubber, which may be called shaving scrubbers. When used in this way the chips can be changed at just the proper time as determined by their complete saturation and failure to arrest the vapors, while when used as a lower layer in the purifying box the changes are determined by the fouling of the purifying material, irrespective of the condition of the chips which may be called upon for more work than they are equal to, or, on the other hand, may have to be taken out of action before being completely saturated, thus making the action irregular, while at the same time the expense of handling into and out of the boxes is greater than it would be in the case of separate vessels.

A discussion of the subject, which should be read by the students, will be found in the Proceedings of the American Gas Light Association, Vol. XV., pages 142 to 147, and a paper describing the experiments made at one large works, and giving the details of the scrubbers used at that works, will be found in Vol. XVII of the same Proceedings, at page 207.

Since the reading of this paper further experiments have been made with modified forms of the P. and A. condenser, and one in which the drum is made of nine concentric cylinders formed from perforated sheets, with holes $\frac{1}{8}$ in. in diameter, has been found to remove all the tar and oil that cause trouble in the purifiers. The condenser is placed between the relief holder and the purifier, and is worked under a differential pressure of about 6 in. to 9 in.

Relief Holders.

110. Explain the use of the relief holder in water gas manufacture.

Ans. "Water gas, as made by the Lowe, or cupola process, is not generated continuously. It is important that the gas should be purified and measured in a continuous flow. The relief holder receives the gas as made from the apparatus, and thus acts as a governor, permitting a continuous flow through the purifying and measuring apparatus, in spite of the intermittent process of generating. It also acts as an equalizer of the gas, which will vary slightly from one period of the run to another."

Impurities.

See answer to question No. 63 for qualitative tests for tar and sulphuretted hydrogen.

Oil Tanks.

111.. Describe two methods employed for "venting" oil storage tanks so as to permit the escape, when the tanks are being filled with oil, of the vapor that has accumulated in them and to prevent the formation of a vacuum while the oil is being pumped out, and state their respective advantages and disadvantages.

Ans. One method for venting oil storage tanks at gas works is to connect the vent pipe either to the gas-holder inlet or outlet, or to some part of the pipe system around the works, such as the foul main.

Another method is to have either a single vent pipe, which branches into two outlets opening into the air, or else to have two vent pipes, and to place a pressure relief valve on one outlet and a vacuum relief valve on the other outlet, being careful to keep the open ends of each pipe covered with brass wire gauze of not less than say 2,500 meshes to the square inch.

The great advantage of the first method is that it entirely prevents the formation of an explosive mixture of air and oil vapor in the top of the tank, since as oil is withdrawn from the tank its place is taken by gas from the holder or pipe system. The disadvantage, which is greatest when naphtha is used and stored in an uncovered tank exposed to the sun's rays, and when the vent pipe is connected directly to the holder outlet or to a pipe to which consumers' services are also connected, is that at times, when the tank is being filled with oil and when the weather is hot, an excessive amount of vapor passes over into the gas being supplied through this pipe and causes it to smoke badly when consumed. This disadvantage is of smaller importance when the tank is roofed over or covered with water, and when heavy oil is used and the vent pipe can be connected into the foul main it practically disappears, and under these circumstances this method of venting is the best possible one.

The second method obviates any such interference with the regulation of the quality of the gas as may result, as stated above, from the first method, but has the great disadvantage of permitting the formation of a mixture of air and oil vapor in the top of the tank, which mixture may be fired and cause more or less damage. It is, however, thought by some good authorities to be preferable to the first method when naphtha is used and stored in tanks exposed to the sun, owing to the trouble experienced under these conditions from the tendency of the vapor-laden gas to smoke. The caps of fine wire gauze placed over the vent pipes should prevent any flame from striking back into the tank, even in case the vapor escaping from the pipes should be accidentally fired. Of course, in normal working no naked light should ever be allowed near an oil tank under any circumstances.

112. What precautions should be taken to protect oil storage tanks from fire, and to prevent the oil from spreading over surrounding territory in event of fire?

Ans. "To protect oil storage tanks from fire, they should be erected as far as convenient from any possible source of fire. They should not be surrounded by combustible material. As a further protection, the top of the tank may be made, as is often the practice, in the form of a pan, which can be kept full of water, protecting the tank from sparks, and keeping the oil cooler than it would be if the sun were allowed to shine directly on the metal. Tanks may be erected in fire-proof buildings, and however erected and of whatever material, they should be, for the protection of surrounding property, encircled with a sufficiently heavy wall of earth or masonry to prevent the escape of the oil, in case a rupture of the metal of the tank should occur."

113. What material would you put on the threads, or on the faces of flanges, when making up the joints in pipe lines to be used for crude oil, naphtha or gas oil?

Ans. The superintendent of a large carburetted water-gas plant gives the following answer as the result of experience in running and maintaining oil lines at the works under his charge.

"Use common brown soap on the threads of pipe lines to be used for crude oil, naphtha or gas oil, first making sure that the threads are clean and full depth and that the oil used in cutting these threads is burnt, or otherwise thoroughly cleaned off, before applying the soap. For the faces of flanges use a close-grained, fibrous cardboard for the small sizes, and either cardboard or a metallic gasket for the larger sizes—the latter preferred. The cardboard should not be more than $\frac{1}{16}$ of an inch thick for any size of flange, and if a metallic gasket is used, it is best made of an outer ring of copper and an inner ring of lead."

Thick shellac varnish is also used on pipe threads for oil lines and works well on lines carrying cold naphtha. Litharge mixed with glycerine is also used, but this becomes too brittle as it hardens to make a good job.

The one thing to be avoided is the use of any material mixed with linseed oil, since the petroleum oil rapidly attacks any such material, and joints made with it soon leak.

114. A cylindrical oil tank of the "cheese-box" type is 22 ft. 6 in. in diameter and 16 ft. 0 in. high. How many gallons of oil will it hold for each inch and each foot of its height, and what will be its total contents when full?

Ans. The area of a circle 22 ft. 6 in. or 270 in. in diameter is, as obtained from the tables of circumferences and areas of circles, 57,256 sq. in., and therefore the tank will contain a volume of 57,256 cu. in. for each inch of its height. An American gallon has a volume of 231 cu. in. 57,256 ÷ 231 = 247.86 + or each inch in height of the tank will contain 247.86 gallons of oil.

Each foot in height will contain 247.86 × 12 = 2974.32 gallons, and the total contents of the tank when full will be 2974.32 × 16 = 47,589 gallons.

Using the contents per inch and per foot, determined as above, a table should be prepared for each oil tank at a gas works, showing the total contents for any height to which it is filled with oil from 1 in. to the full height.

115. A cylindrical oil tank, placed with its axis horizontal, is 4 ft. 0 in. in diameter and 20 ft. 0 in. long. How would you determine the amount of oil it holds for every inch in depth of the oil from 1 in. to 48 in.?

Ans. The simplest method of determining the amount of oil contained in a cylindrical oil tank set with its axis horizontal, when the tank is filled to certain levels, is a graphical one. On a piece of paper spread on a drawing-board or a smooth floor, draw a semicircle with a radius equal to that of the tank. Draw a line passing through the centre and stopping at each end at the circumference, or, in other words, draw a diameter of the circle. Then draw lines parallel to this diameter and 1 in. apart until the whole semicircle has been divided into strips 1 in. wide. The area is now divided into a number of quadrilaterals which are practically trapezoids, since the portion of the circumference included between adjacent lines is practically a straight line, with a segment of the circle at the bottom. An isosceles triangle, equivalent in area to this segment, can be formed by erecting a perpendicular at the middle point of the lowest one of the parallel lines, and, from a point on this perpendicular a little outside of the circumference of the circle, drawing a line on each side down to the base at the proper inclination to make it cut the circumference of the circle at such a point that the area included between the line, the circumference and the perpendicular and lying outside of the circumference, is equal to the area included between the line, the circumference and the lowest of the parallel lines and lying inside of the circumference. A very close equality between these areas can be secured by eye after one or two trials. If the tank is a small one and the curvature of the circumference sharp, it may be necessary to draw the parallel lines only ½ in. apart in order not to have the portion of the circumference between two adjacent lines deviate too much from a straight line and in the present case it is necessary to do this for the lower 10 in. of the semicircle, the whole being thus divided into fourteen 1 in. strips, nineteen ½ in. strips and a segment having a height of ½ in.

The semicircle having been divided up in this way the calculations are very simple. Starting with the triangle measure the lengths of its base and its altitude in inches and multiply the base by one-half the altitude. The product is the area of the triangle in square inches. Multiply this by the length of the tank in inches and the product is the volume in cubic inches of the space enclosed between the bottom of the tank and a plane parallel to the axis of the cylinder and passing through a horizontal line drawn 1 in. above the lowest point in the circumference. Divide this volume by 231 (the number of cubic inches in a gallon) and the quotient is the number of gallons in the tank when the liquid in it is 1 in. high. Having determined this the next step is to obtain the area of the trapezoid immediately above the triangle. To do this, measure the length in inches of each of its two parallel sides, add these lengths together, divide the sum by 2 and multiply the quotient so found by the length of the perpendicular between these sides, which will be either ½ in. or 1 in. The product is the area of the trapezoid. Multiply this by the length of the tank in inches and divide by 231, and the quotient is the number of gallons contained in the portion of the tank included between two planes parallel to the axis and passing through the upper and lower sides, respectively, of the trapezoid. The sum of this number and of the number previously obtained is the total number of gallons in the tank when it is filled to the same height as the upper side of the trapezoid. In the same way the number of gallons that the tank will hold for each strip represented by a trapezoid can be determined and added to the total number of gallons for all the strips below it to get the total content of the tank up to that point. When the contents have been figured for each inch up to the centre, those for each inch above the centre can be obtained by adding, one at a time, the volumes of the corresponding strips as already determined, since each strip in one semicircle will have its counterpart in the other.

For the tank specified in the question the triangle judged to be equivalent to the segment with a height of $\frac{1}{2}$ in. has a base of 9.22 in. and an altitude of 0.73 in. Its area is therefore $9.22 \times 0.365 = 3.37$ sq. in. In the trapezoid immediately above it the lengths of the parallel sides are 9.84 in. and 13.78 in. respectively and the perpendicular distance between these sides is $\frac{1}{2}$ in. Its area is therefore $\frac{9.84 + 13.78}{2} \times \frac{1}{2} = \frac{23.62}{4} = 5.9$ sq. in. and the total area of the segment with a height of 1 in. is $3.37 + 5.9 = 9.27$ sq. in. The length of the tank is 20 ft. or 240 in., so that the volume contained when it is filled to a depth of 1 in. is $9.27 \times 240 = 2224.8$ cu. in., and the content in gallons is $\frac{2224.8}{231} = 9.6$ gallons. Working in this way the number of gallons contained for each inch in depth of the oil can be found and a table made up from which to determine the content for any given measurement.

The areas of the different segments can also be calculated by any one of the several rules given in engineering handbooks, but it takes much longer to do the work in this way than by the graphical method, and the errors in the results obtained by the latter are well within the limits of error due to inequalities in the tank itself. For tanks over 8 ft. in diameter, however, the graphical method can hardly be used on account of the difficulty of finding a suitable surface sufficiently large to hold the drawing.

Residual Tar.

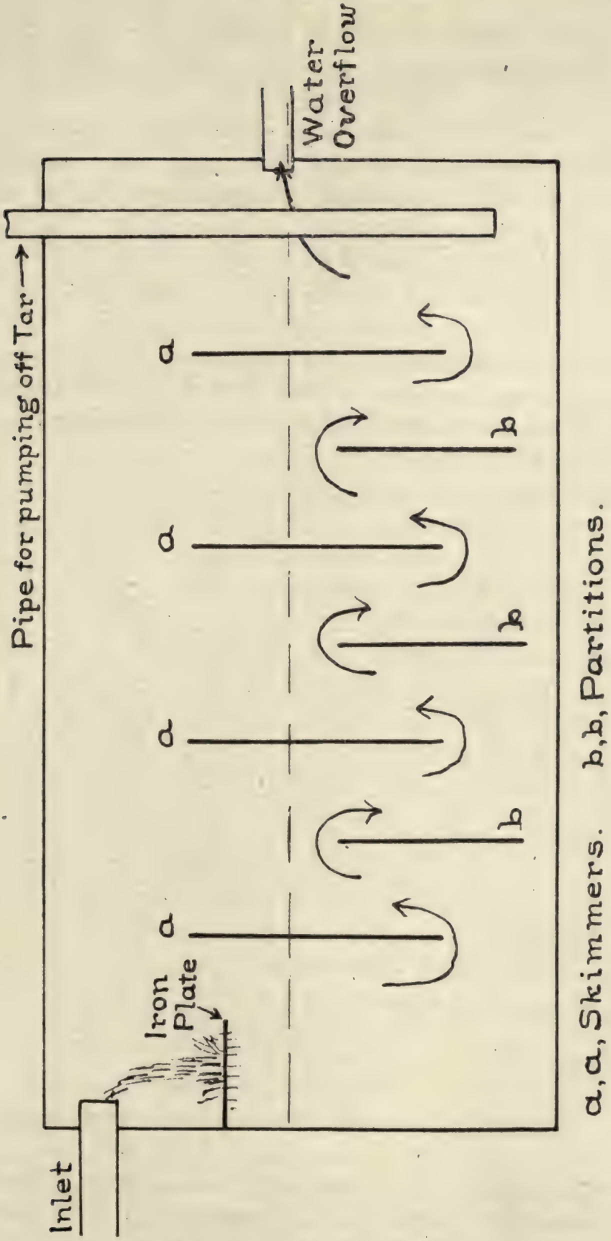
116. Give a description, illustrated with sketches, of some form of apparatus for separating the oil tar produced in the

manufacture of carburetted water-gas from its accompanying water, the purpose being to remove all appearance of tar from the works' drainage.

Ans. An effective apparatus for separating the oil tar produced in the manufacture of carburetted water-gas from its accompanying water, is shown in the cut, and consists of an oblong rectangular box of wood or iron, say 4 ft. wide, 5 ft. deep, and 16 ft. long, buried in the ground to such a depth as to receive all washbox and drip water, and to empty into a sewer or other drain. This box is provided with a series of cross partitions at intervals of 18 in. or 2 ft., every other partition reaching from within, say, 5 in. of the bottom of the box, to within 4 to 6 in. of the top surface of liquid in the box. Alternating with these partitions are others which reach from within 2 ft. of the bottom of the box, up above the surface of the liquid, and are called skimmers. The liquids to be separated are admitted at one end into the box (if possible from a height of several feet), falling on an iron plate and thence flowing through the separator. This striking of the tarry liquids on an iron plate helps to break up the vesicles of tar and water. Another way would be to urge the stream of tarry water against a plate by the aid of a steam jet. The liquid flows, the slower the better, over and under the partitions, each reversal of current helping to precipitate the tar to the bottom; any light oils come to the top surface, and are held by the skimmers until removed.

The wider and deeper the box, the slower the motion of a given quantity of fluid per hour; the longer the box, the more complete the separation. The higher the bottom of the skimmers from the bottom of the box, the greater the capacity of the box to hold the separated tar between periodical drawings off. The bottoms of the other partitions are only above the bottom of the box, to enable accumulated tar to be drawn off from one end; the tar will never be completely drawn off, so that there is no danger of liquid flowing direct from one end of the box to the other under the partitions.

The bottoms of the skimmers should not be too high above the bottom of the box, however, for the total depth of box, or



TAR AND WATER SEPARATOR.

the zigzag reversals of current would be too slight. Keep the box covered with hatches, and if necessary warm with steam pipes in winter to keep the temperature about 150° Fahr.

117. What is the fuel value of the oil tar produced in the manufacture of carburetted water-gas, and, consequently, what is the price that should be obtained per gallon to make it worth while to sell, instead of burning, it? The price of steam coal may be taken as $3.50 per net ton.

Ans. The only information that has been published, as far as is known to the Trustees, as to the fuel value of the oil tar produced in the manufacture of carburetted water-gas is that given in a paper, "The Fuel Value of Residuals," read by Mr. Chas. F. Prichard at the meeting of the American Gas Light Association in 1901.

Mr. Prichard took as a basis of value a first-class steam coal having a calorific value of 14,385 B. t. u. per pound and giving an evaporative duty per pound, under every-day working conditions in the boilers of an electric light plant, of 9.8 lb. of water from and at 212°. The cost of this coal is, in the question, assumed as $3.50 per net ton.

The calorific value of the oil tar used by Mr. Prichard, as determined by a bomb calorimeter test, was 17,193 B. t. u. per pound, and the average evaporative efficiency per pound, when used under boilers under the same conditions as the coal, was 14.9 lb. of water from and at 212°. As the weight of a gallon of this tar was 9.58 lb. the weight of coal equivalent for use as boiler fuel to a gallon of tar can be found from the proportion $x : 9.58 = 14.9 : 9.8$ according to which $x = \frac{9.58 \times 14.9}{9.8} = 14.56$ lb. Since the coal is worth 0.175c. per pound the value of the tar for fuel purposes is 0.175c. × 14.56 = 2.5c. per gallon, and if it cannot be disposed of at this or a higher price it should be burned.

Mr. Prichard's paper can be found in the Proceedings of the American Gas Light Association, Vol. XVIII, page lxxvii; in American Gas Light Journal, Vol. LXXV, page 807, or in Progressive Age, Vol. XIX, page 517.

PART 3.—COMMON TO BOTH COAL AND CARBURETTED WATER GAS.

Coal Handling Machinery.

118. Describe briefly and generally some system of machinery for unloading coal from barges and depositing it in the coal shed.

Ans. Every system of machinery for unloading coal from barges and depositing it in the coal shed is composed of two parts, one for taking the coal from the barge and depositing it upon the dock at some point, usually at a high level, from which it can be taken into the shed, and the other for transporting the coal from such point of deposit to the proper position in the shed.

For the unloading proper the simplest combination is a mast and boom hoist worked by horse-power, and using buckets, or tubs, that have to be dumped by hand. But when any large amount of coal has to be handled the hoisting is done by steam. The average apparatus consists of a steam hoisting engine fixed on the dock, and a derrick movable along a track laid along the dock parallel to the water line, and carrying an inclined boom, a traveller free to run in and out on the boom, a coal hopper, a working platform on a level with the tracks in the coal shed and fitted with a continuation of these tracks running over a platform scale, and the necessary pulley blocks to guide the hoisting rope along its path from the engine up to the top of the derrick, over the inside end of the traveller and around the loose block carrying the hoisting hook, to point of final attachment on the outer end of traveller.

Very frequently a boiler is part of the plant, but in most gas works it is cheaper to pipe steam from the main boilers to the dock, than it is to use a small separate boiler for the purpose.

The hoisting engine is made with two cylinders with pistons connected to opposite ends of a shaft by cranks set at an angle of 90° with each other. The hoisting drum derives its motion from this shaft by friction gears or by toothed gearing and a friction clutch against which the drum is pressed by any suitable means, such as a lever turning a screw with threads cut to a very rapid pitch, the point of the screw being fastened to the drum, so that a quarter revolution of the lever carries the drum from no contact to full friction. Braking, when lowering tubs, is accomplished by holding the drum more or less tightly against the clutch, and a load is held stationary by pressing the drum tightly against the clutch with just enough steam admitted to the cylinders to prevent motion in either direction, or a special brake may be provided. The throttle valve handle and friction lever are so arranged that the first can be worked with the left hand, while the second is handled with the right ; the brake, when one is used, being worked by the foot.

The derrick is usually framed of wood, iron being sometimes employed in later construction.

The operation is as follows : The derrick having been moved opposite the desired track in the coal shed, the wheels on which it travels are clamped, the guy ropes fastened, and the boom swung out with stop set so the traveller will be held at the proper distance from the dock when the tubs are lowered. The full tub, holding about ½ ton of coal, is hooked on and the engine started. The tub is raised vertically, until the hook block is brought tight against the traveller. As the winding up of the rope continues the traveller is drawn in and up along the boom, until the tub, made self-dumping by having the points of attachment of the handle below its centre of gravity when loaded, is brought against a tripper that raises the back lever catch and turns over, emptying the coal into the derrick hopper ; the tub when empty righting and locking itself in readiness to be run out with the traveller and lowered, when this comes to rest against the stop, as its weight unwinds the rope from the drum.

The second portion of the system, that for transporting the coal from the derrick hopper to the place of deposit in the coal shed, consists simply of the necessary tracks and cars propelled by hand, or gravity; the cars, filled by a shoot at bottom of the hopper and weighed, being in the first case run into the shed, and dumped, by hand. In the second case the tracks are laid to slope down from the derrick, and as the loaded car runs down the incline it picks up, at the proper point, a stop set on a rope attached to a heavy counterbalance weight free to rise and fall through a certain distance. The momentum gathered by the loaded car in its descent is sufficient to raise this weight, and the car being dumped automatically soon after picking up the rope, the lighter weight of the empty car is overcome by the resistance of this counterbalance weight, which then falls, giving the car sufficient impetus to carry it back to the starting point on the derrick.

Conveyors or cable railways are also used to carry the coal into the shed.

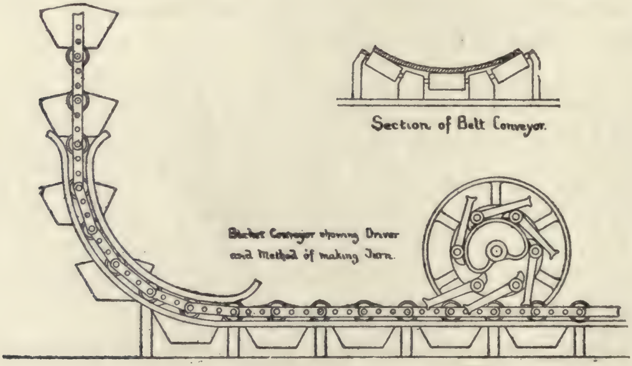
119. Give a description, illustrated with sketches if necessary, of some form of conveyor suitable for handling either anthracite or bituminous coal in the condition in which it is usually received at a gas works.

Ans. One form of conveyor that is extensively used for handling coal consists of a series of buckets linked together by two chains made of heavy steel bars, the buckets being pivoted between the chains in such a way that they are always kept upright by gravity, no matter whether the chains run horizontally or vertically or at any angle between horizontal and vertical. When travelling horizontally or along an inclination the conveyor is supported by wheels set between the bars of each chain and running on a track, but when travelling vertically it may be allowed to hang free. Changes of direction from horizontal to vertical are made by giving the proper curve to the track. The size of the buckets is regulated by the size of the coal to be carried and the rate at which it is to be handled.

The chains are driven by pawls arranged around a wheel and guided by a cam, and engaging with pins provided for the purpose along the chains, the power for turning the pawl-wheels being usually derived from a small double cylinder engine. This driving arrangement can be put at any point of the chain wherever it is most convenient to have it.

The buckets can either be entirely separate or else made so that when running horizontally the edges of adjacent buckets either touch or overlap. In the latter case material can be spouted into the conveyor in a constant stream without danger of any falling between the buckets and being wasted. For the separate buckets special fillers are used to put a fixed amount in each bucket and prevent any loss between the buckets. At the proper point a dumper upsets and empties the buckets either directly on to the pile underneath or into a shoot. Both fillers and dumpers are movable and can be set at any desired points on the horizontal runs.

With this form of conveyor coal can be carried both vertically and horizontally and there is no necessity for providing separate elevators. On the cut is shown the driving mechanism and the arrangement of buckets, chain and track.


Section of Belt Conveyor.
Bucket Conveyor showing Driver and Method of making Turn.

CONVEYORS.

Another form of conveyor frequently used for coal consists of an endless belt driven by ordinary belt pulleys and supported and made to assume the form of a curved trough by numerous sets of three rollers each, one of the rollers being placed horizontally under the middle of the belt and the other two, one under each side of the belt, set slightly higher and at an acute angle with the horizontal. The coal is delivered on to the belt by a spout and dumped at any desired point by a movable dumper composed of a frame carrying pulleys around which the belt passes in such a way that it overhangs and the coal drops off into a shoot.

This form of conveyor can only work horizontally or at a very slight angle and along straight lines, requiring the provision of an elevator for vertical lifts, but for horizontal work it is efficient and can be installed at a comparatively small cost.

Boilers.

120. If you had to install a new boiler plant, what general considerations would influence your choice of type of boiler to be used?

Ans. The principal general considerations influencing the choice of type of boiler for any particular installation are, the location and space available; the kind and cost of fuel; the nature of the feed-water; the steam pressure to be carried; the facilities for having repairs made, and the first cost of the boiler and cost of maintenance.

A few applications of these considerations may be indicated.

When the feed-water is such as to cause considerable deposit in the boiler, it is best to choose the simple cylindrical form, or a simple flue form, on account of the ease with which these types can be cleaned. The ability to obtain a good fuel at a low cost would also lead to the same choice, owing to saving in interest on first cost more than counterbalancing loss of economy in fuel. Difficulty in having repairs made would also lead to the choice of these types.

With higher prices for fuel and better feed-water, the more complicated flue or tubular boilers are selected on account of greater fuel economy, and under the same circumstances the necessity for such a location of the boiler as would make the results of a possible explosion particularly disastrous, would dictate the selection of one of the so-called "safety" or "sectional" boilers, even though cost and other considerations weighed against its adoption.

The desirability of using a low grade fuel produced on the works, and practically unsalable, might also turn the scale in favor of a special type not otherwise the most desirable.

Of course, in each case, all conditions, financial as well as engineering, must be carefully considered in making a choice of type.

121. What are the factors in steam boiler construction which influence the efficiency of the boiler?

Ans. The chief factors in steam boiler construction which determine the efficiency, that is the percentage of the total heat furnished by the fuel consumed in the furnace which is used in the formation of steam, are,

1st. The ratio of heating surface to grate surface when the rate of consumption of fuel per square foot of grate surface is an average one; or in any case the ratio between the quantity obtained by dividing heating surface by grate surface and the rate of consumption of fuel per hour per unit of grate surface, and,

2nd. The activity of the circulation of the water in the boiler over the heating surface.

Up to a certain point any increase in these ratios or in the activity of circulation leads to a greater efficiency, as by such increase is secured that low temperature of the escaping gases which is essential to economy of operation. The efficiency does not seem to be practically affected by variations in the thickness of the plates or tubes forming the heating surface between the limits imposed by structural conditions, though ribbing these tubes or studding the plates with pins projecting into the fire space on one side and the water on the other has a good effect by increasing the heating surface.

From the figures obtained from a large number of boiler tests made by him, Mr. Geo. H. Barrus draws the following conclusions as to the relation necessary between grate surface and heating surface, and in fire tube boilers between grate surface and area of tube opening.

1st. A ratio of heating surface to grate surface of 36 to 1 with anthracite coal and of 45 to 50 to 1 with bituminous coal is sufficient to secure the full efficiency, when the rate of combustion is from 10 to 12 lb. of coal per square foot of grate surface per hour.

2nd. In tubular boilers the area of tube opening should be from $\frac{1}{9}$ to $\frac{1}{10}$ the grate surface for anthracite, and from $\frac{1}{8}$ to $\frac{1}{7}$ the grate surface for bituminous coal.

122. What points are to be observed in the design of a boiler setting in order to make it possible to obtain good efficiency of operation?

Ans. The chief points in the design of a boiler setting which affect efficiency of operation are the area of grate surface, the size of combustion chamber, ease of getting at all parts of the heating surface for purposes of cleaning, and the prevention of loss of heat and of influx of air through the walls of the setting.

The proper area of grate surface depends upon the character of the fuel and the area of heating surface of the boiler. The grate must be large enough to burn the quantity of fuel required without the necessity for an excessive draft, but not so large in proportion to the heating surface that the products of combustion will, owing to contact with an insufficient amount of boiler surface, pass out to the chimney at too high a temperature. Knowing the amount of steam that the boiler will be required to furnish and the weight of water that can be evaporated by a pound of the fuel to be used, the grate surface can be figured on the basis of a consumption of 10 lb. of anthracite and 15 lb. of bituminous coal per square foot per hour. This will give the largest area that will be required, which can be reduced, if found advisable, by bricking over part of the grate near the walls. The proportion between grate surface and heating surface should, according to Mr. Geo. H. Barrus, be as 1 to 36 with anthracite coal and as 1 to 45 to 50 with bituminous coal when the rate of combustion is from 10 to 12 lb. of coal per square foot of grate surface per hour. If the rate of combustion is to be higher, there must be more heating surface in proportion to grate surface. The proportions given are those which were found in the boilers which showed the best efficiency out of a great number tested by Mr. Barrus.

The combustion chamber, that is, the space above the grate between it and the boiler, should be made large enough to enable the combustion to be completely finished before the products come in contact with the boiler. The temperature of the outside surface of the boiler shell is only a very little higher than that of the water in the boiler and much below that required to carry on the combustion of the gaseous products of the partial combustion of the fuel, and therefore if these products come into contact with the boiler while still unconsumed their temperature is reduced and combustion stops, with a consequent waste of fuel. As bituminous coal gives off more gaseous products that are combustible than does either anthracite coal or coke, a larger combustion chamber is needed for the first than is required for the others. As the horizontal area of the combustion chamber is restricted by the size of the boiler, the increase in volume can only be obtained by an increase in the height, that is, the distance between the top of the fire and the lowest point of the boiler. With anthracite coal this height may be made as small as 18 in., but with bituminous coal it must be made much greater, a height of four or five feet being required with coal giving off a large proportion of volatile matter. The necessity of providing sufficient room to enable the combustion to be fully completed before the products are cooled below the temperature of ignition is not always understood, but where this is not done the efficiency of the boiler suffers.

When the setting is not built so that all parts of the heating surface can be easily reached for cleaning, the parts that cannot be reached will soon become coated with soot and flue dust and rendered very inefficient.

To prevent loss of heat and influx of air through the walls of the setting, the outer walls should be made at least 24 in. thick, with a 2 in. air space in the middle of the wall, and where two or more boilers are set in a battery, each division wall should be in two parts with a half-inch space between them. This prevents radiation and also allows for expansion and contraction and thus reduces the liability of the walls to crack, a liability especially great in the case of a solid division wall with the boiler on one side let down while that on the other is under fire. The setting should also be well braced with buck-stays and tie-rods made strong enough for the work they are called upon to do. The part of the boiler above the setting should be covered with a plastic non-conducting material in a layer 2½ in. thick. Such a covering is a better non-conductor of heat and also lighter than the brick arch very generally employed, besides allowing greater freedom of access to the boiler in case of a leak.

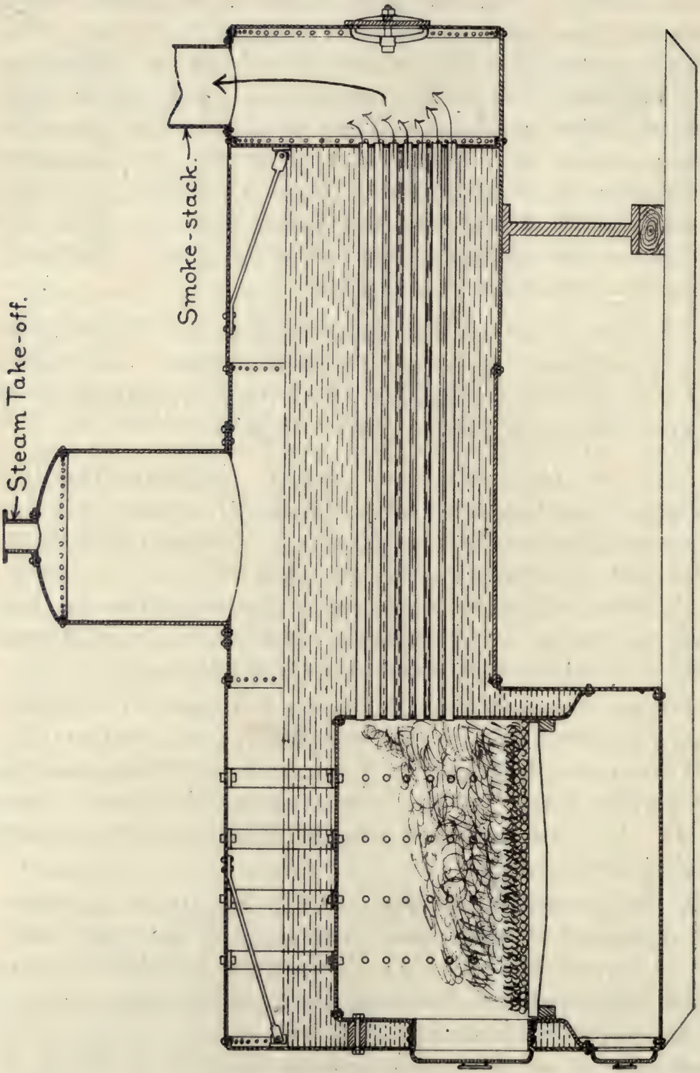
123. Give a general description, illustrated with sketches, of a locomotive-type boiler, a horizontal water tube boiler, and a vertical water tube boiler, with the general arrangement of grate and waste gas flues used with each.

Ans. A "Locomotive-type" boiler, so called because it is universally used in locomotive construction, consists of a fire-box of rectangular form, attached to a cylindrical shell closely filled with fire tubes running from the fire box to a chamber at the other end of the boiler, which chamber forms the base of the smoke stack. The products of combustion pass through the tubes and chamber, directly to the smoke stack.

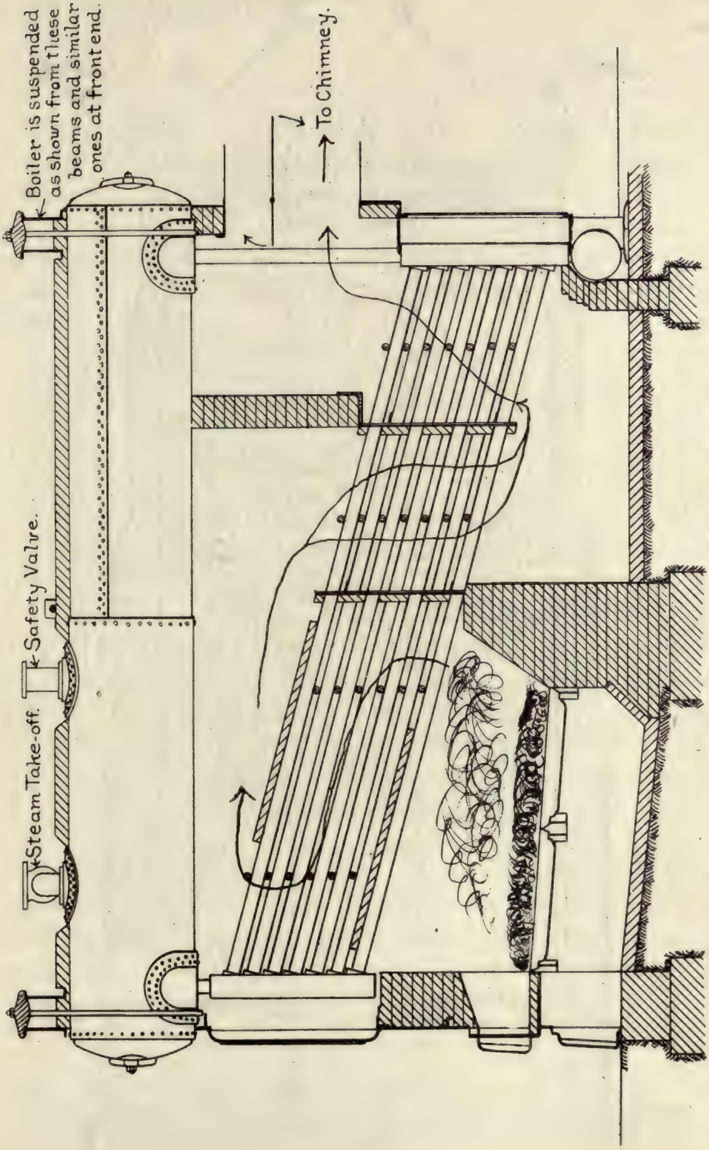
The flat sides and crown of the fire-box have to be closely stayed to enable them to support the pressure upon them.

This type is largely used, apart from locomotive practice, for portable boilers. The cut shows the boiler mounted upon skids. It is also frequently mounted upon wheels for greater facility of movement.

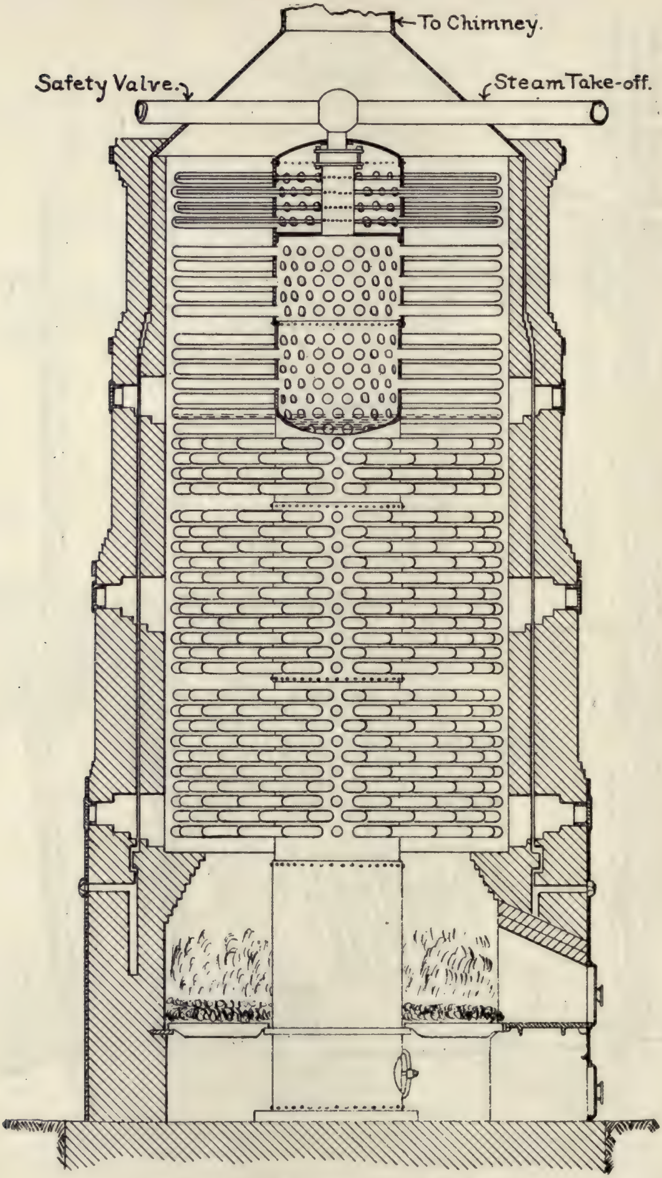
A "Horizontal Water Tube" boiler consists of a cylindrical shell made of boiler plate, with heads at each end and a set of water tubes below the shell, either parallel to or at a slight angle with the axis of the shell, and connected to it at both ends, such connection being made in various ways. The water line is usually maintained at about the middle of the shell, which thus acts as a steam and water drum, the steam being taken off from the top by a dry pipe, extending the full length of the drum. The tubes furnish the principal heating



LOCOMOTIVE-TYPE BOILER.


Boiler is suspended as shown from these beams and similar ones at front end.
To Chimney.
Safety Valve.
Steam Take-off.

HORIZONTAL WATER-TUBE BOILER.



VERTICAL WATER-TUBE BOILER.

surface, and the shell can be made of smaller diameter for equal capacity than in boilers of the cylindrical type, thus enabling a higher pressure to be carried without unduly increasing the thickness of the plates of which it is made.

One method of setting is shown on the cut. The products of combustion pass up between the tubes, which should be staggered to secure the best utilization of the heat, to the bottom of the drum, then down between the tubes, and up again to the chimney flue, as shown by the arrows. The boiler is preferably supported independently of the brick-work of the setting.

A "Vertical Water Tube" boiler consists of a long cylindrical shell (made of boiler plate and fitted with heads), set vertically, to which are fastened tubes projecting out from the circumference. These tubes are either comparatively short with closed ends, in which case they are set radially with axes horizontal, or they are long and start from the shell, follow, for a greater or less distance, a spiral course having the same axis as the shell, and return to the shell at a point above and to one side of the starting point. In either case these tubes should be staggered in order to break up the currents of waste gases, and prevent any of these passing out through the stack without coming in contact with heating surfaces. Some of the tubes are above the water line and the steam is taken from the boiler by small pipes radiating from the main steam pipe and extending to the outer ends of such tubes.

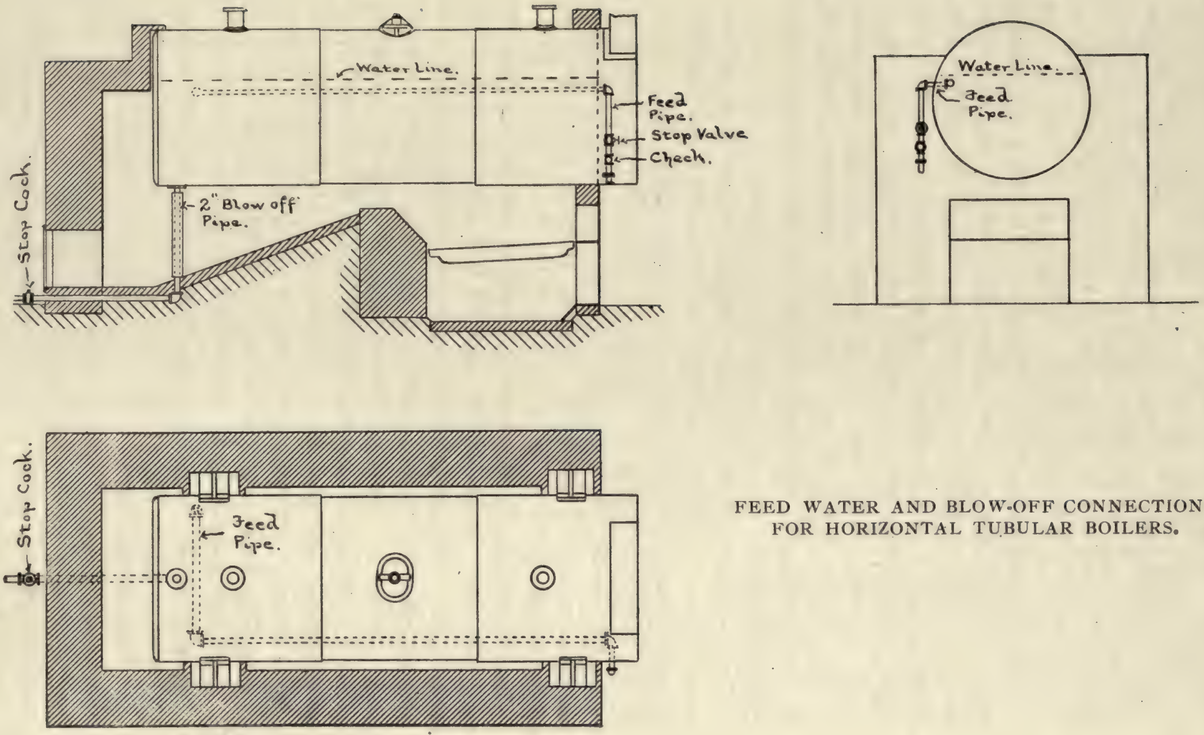
As shown on the cut, the setting is simply a cylinder of brick work enveloping the boiler close to the outside of the tubes, and ending in a wrought iron stack. The boiler rests upon its own foundation, and is entirely independent of the brick work. The products of combustion pass directly up between brick-work and shell, being deflected from side to side by the tubes.

124. Give a description, illustrated with sketches, of the proper manner in which to make the feed water and blow-off connections for steam boilers, and state the faults that are to be guarded against in making such connections.

Ans. The manner of making the feed-water and blow-off connections to boilers necessarily varies with the type of boiler employed. Since horizontal return tubular boilers are used more extensively in gas works than any other type, this answer will be confined to the manner in which these connections should be made for boilers of this type.

Two important points to be observed in the arrangement of the feed-water pipe in any case are that the comparatively cold feed-water should not be delivered directly against any portion of the shell of the boiler, especially if such portion is exposed to the fire, or to contact with the products of combustion, and that the outlet of the pipe should be so located with reference to the water-line, that as little as possible of the water would be siphoned out of the boiler in case of any accident to the feed-pipe accompanied by failure of the check valve to work.

Even if the feed-water is heated, it is much colder than the shell, and if it is allowed to impinge directly upon the shell, the metal is severely strained by the local cooling to which it is subjected while hot at all other points. It is, therefore, very poor practice to introduce the water directly at the bottom of the boiler, or when it is introduced at a higher point, to have it delivered in a direction that carries it directly against the bottom of the shell. These, however, are very common faults in connection with feed-water pipes. A good feed-water connection is shown on the cut. The pipe is brought up on one side of the boiler at the front (the check and stop valves being placed in the order named at a convenient height on the vertical run) to a point one or two inches below the low-water line, and then run horizontally parallel to the face of the boiler through the front smoke-box to a point about 6 in. from the side; then turned and run back through the front and parallel to the side of the boiler to about a foot from the back end; then again turned, still being kept horizontal, and carried at right angles across the boiler to a point about 6 in. from the shell on the other side where it ends in an elbow with the open end down. When the pipe is run in this way, the feed-water has an opportunity to become



FEED WATER AND BLOW-OFF CONNECTIONS FOR HORIZONTAL TUBULAR BOILERS.

heated by passing through it and is delivered at a point where the water in the boiler is coolest and where there is apt to be a downward current. As the feed-water, even when admitted in this way, is cooler than the water in the boiler, it has a tendency to fall and its admission at the point named helps to secure a better circulation in the boiler.

This arrangement cannot be used with water containing much bi-carbonate of lime, since the deposit formed when water of this description is heated, would soon fill up the long internal pipe. In such cases, it is advisable to use a pipe only a few inches long, opening into an open trough or a pipe of larger diameter with the top cut away; this pipe extending the full length of the boiler. Such an arrangement distributes the water well and reduces to a minimum the danger of feed-pipe stoppages.

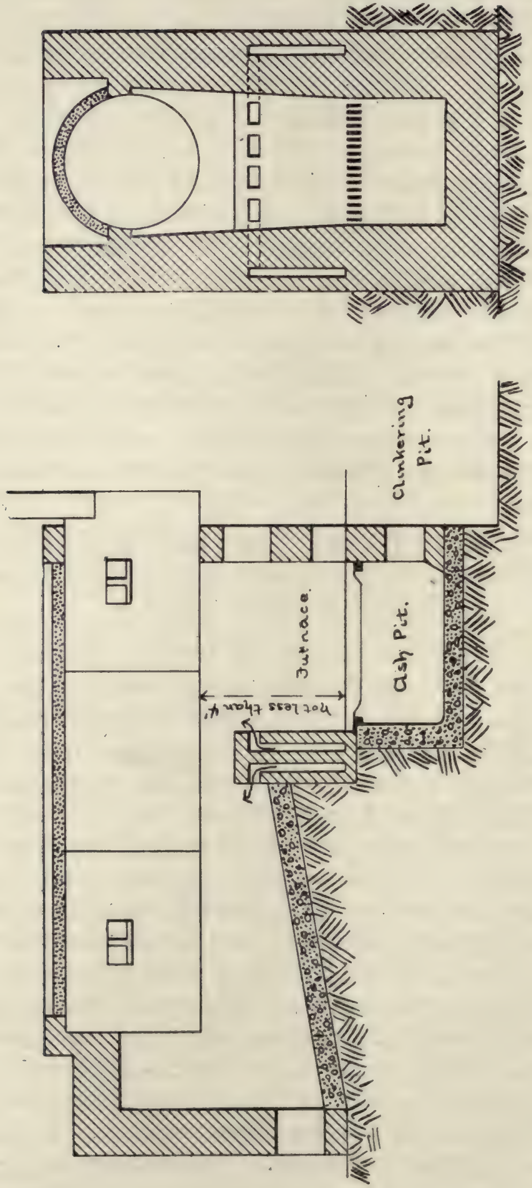
The feed-pipe to every boiler should be provided with a check valve set close to the boiler, and in such a position that the valve opens vertically so that its weight assists the pressure of the boiler in closing it. A stop valve should be placed between the check valve and the boiler so that the check valve can be repaired, if necessary, without running the water out of the boiler.

The blow-off pipe is connected to the bottom of the boiler at the back end. It should be made of iron and not of brass or copper, since the latter metals are eaten away by the action of the hot gases to which a portion of the blow-off pipe is necessarily exposed. The part of the pipe so exposed should be covered with some non-conducting material, asbestos rope wound round the pipe being often used. Only straight way valves or stop cocks should be employed for shut-offs, and the openings in them should be at least the full size of the pipe. A tortuous passage, such as is found in globe valves, affords an opportunity for the trapping of loose pieces of scale against which more pieces collect until the pipe is completely choked up. With a straight way opening of the full size of the pipe, this cannot happen. Gate valves are open to the objection that scale can accumulate in the depression into which the bottom of the valve fits when it is closed and thus prevent the valve from closing tight. In spite of its tendency to stick, a full opening stop-cock forms the best shut-off for a blow-off pipe, but it must be opened full every time the blow-off is used, and care must be taken to shut it slowly to avoid subjecting the pipe to the great increase of pressure produced when the flow of water is stopped abruptly by the sudden shutting of the stop-cock, since this pressure will sooner or later cause a burst, either in the pipe or in the fittings through the strain which it throws upon them. A tee should be inserted in the blow-off pipe just behind the cock so that its tightness when closed can be determined by taking the plug out of the side outlet of the tee and observing whether any water is trickling through the pipe. A tight joint should be made between the end of the blow-off pipe and the drain into which it is led to prevent the hot water splashing back on the boiler attendant. The blow-off pipe should be of good size, at least 2 in. in diameter.

125. Give a description, illustrated with sketches, of some form of furnace for horizontal tubular boilers adapted to give a good evaporation per pound of gas coke.

Ans. The boiler furnace illustrated on the accompanying cut is one that was designed and is used by a gas company which also operates the electric light and power plant in its city. When burning coke in the ordinary boiler furnace in the electric light plant it was found that a comparatively low evaporative efficiency was obtained from it, especially when the boilers were being worked at nearly their rated capacity. The reason for this seemed to be that, owing to the open character of a coke fire, a considerable excess of air was drawn through it when burned with the thin fuel bed customary in a boiler furnace, and that this excess of air reduced the efficiency by carrying a large amount of heat out of the chimney.

To avoid this effect, furnaces were constructed as shown on the cut. These furnaces are made much deeper than the ordinary ones, the distance from the grate bars to the bottom of the boiler being not less than four feet. It is thus practically a generator furnace. The primary air is admitted through the ash pit in the usual way and a supply of second-



DEEP FURNACE FOR BOILER BURNING COKE.

ary air enters through two air ports, one in each side wall of the furnace just below the boiler front. Each port opens into a flue in the side wall which runs back to the bridge wall, and into two flues in this wall. From one of these the air escapes by openings to the front and from the other by openings to the back, as shown on the cut. The secondary air required is thus delivered, from both the front and the back of the bridge wall, to the gas produced in the deep fuel bed. The amount of secondary air admitted must, of course, be proportioned to the amount of gas being produced in the furnace.

While with the ordinary boiler furnace coke had been found to give evaporative results from 10% to 15% lower than those obtained from steam coal in the same boilers, when the furnaces described were used the evaporative efficiency of the coke was brought up to an amount equal to that of the coal. The work of firing with this furnace is stated to be easier than with steam coal and the ordinary grate. The repairs are small and the fire has to be clinkered only once in a day of twenty-four hours.

126. How much grate surface should be allowed in setting a horizontal return tubular boiler 4 ft. 0 in. in diameter and 16 ft. long and containing forty-eight 3 in. tubes? Consider that gas coke will be the fuel used, and give the reasons for your answer.

Ans. Since the rate at which the fuel can be burned, and consequently the rate at which steam can be made in a boiler, depends upon the amount of grate surface, this surface should be as large as is consistent with the efficient utilization of the heat produced in the furnace. To utilize the heat efficiently it is necessary to have ample heating surface in proportion to the grate surface, so that the products of combustion will come in contact with sufficient heating surface to be well cooled down before they escape to the chimney. The area of grate surface should therefore bear a certain relation to that of the heating surface, and it has been found by experience that this relation varies with different classes of fuel. With fuels containing a comparatively large amount of volatile matter, which burn with a long flame, it is necessary, in order to secure the same efficiency, to have more heating surface per square foot of grate surface than is required with fuels which contain no volatile matter, and so burn either with no flame or with a very short one. From the information gained from the results of a great number of boiler tests, Mr. G. H. Barrus states that the best results with bituminous coal are obtained when the heating surface is from 45 to 50 times as large as the grate surface, while with anthracite the ratio need only be 36 to 1. Coke is similar to anthracite in having all the carbon fixed, but since lump coke burns more freely than anthracite, it is well to take a higher ratio for the heating surface and make heating surface divided by grate surface equal 40. For coke breeze, which makes a more compact fire that burns less freely, the proportion can be made 30 to 1, the larger grate being necessary to enable the same quantity of fuel to be burned per hour.

The heating surface of the boiler covered by the question can be found by the following rule, given in Kent's Mechanical Engineers' Pocket-Book:

"Take the dimensions in inches. Multiply two-thirds of the circumference of the shell by its length; multiply the sum of the circumferences of all the tubes by their common length; to the sum of these products add two-thirds of the area of both tube sheets; from this sum subtract twice the combined area of all the tubes; divide the remainder by 144 to obtain the result in square feet."

The boiler being 4 ft. 0 in., or 48 in. in diameter, two-thirds of the circumference of the shell is equal to $\frac{48 \times 3.14 \times 2}{3} =$ 100.48 in., and the length of 16 ft. 0 in. is equal to 192 in. The product of these figures is 19,292.16. The circumference of a 3-in. tube is 9.42 in., so the sum of the circumferences of 48 tubes is $9.42 \times 48 = 452.16$, and $452.16 \times 192 = 86,814.72$. $19,292.16 + 86,814.72 = 106,106.88$. The area of the tube sheet, which is 48 in. in diameter, is 1,809.6 sq. in., and of the two sheets twice this, or 3,619.2. Two-thirds of 3,619.2 is 2,412.8, and $106,106.88 + 2,412.8 = 108,519.68$.

The area of a 3-in. tube is 7.07 sq. in. and twice the area of 48 tubes is equal to 7.07×96, or 678.72. $108{,}519.68 - 678.72 = 107{,}840.96$, and $\frac{107{,}840.96}{144} = 748.90$. That is, the heating surface is 748.90 sq. ft.

Taking the grate surface as $\frac{1}{40}$th of the heating surface, we have as the area of the grate for lump coke $\frac{748.90}{40} = 18.72$ sq. ft., while for breeze it would be $\frac{748.90}{30} = 24.96$ sq. ft.

In gas works, where breeze is certain to be used more or less, the grate should be made of the larger area, which can be reduced at any time if lump coke is to be used as a regular thing.

127. Give a description of a furnace and setting for horizontal return tubular boilers suited for the use of coke breeze as the boiler fuel, and state how you would obtain the draft required for the combustion of the fuel.

Ans. Provided there is sufficient draft to overcome the greater resistance caused by the more compact nature of the fuel bed formed by gas coke breeze as compared with that formed by either coke or coal, breeze can be burned with fair economy in an ordinary horizontal return tubular boiler setting under natural draft. It is necessary to have a grate with openings small enough to prevent the breeze from falling through, and it is well not to have the grate too far below the boiler, say from 2 ft. 0 in. to 2 ft. 6 in., since the breeze burns with a short flame and should be used in a thin bed. When the breeze is put in a little at a time and the fire kept thin and clean, fairly good results can be obtained with a furnace of this kind.

But natural draft is necessarily strongest on top of the fire and when a sufficient vacuum is maintained above a breeze fire to enable enough air to come through the fuel bed to produce the heat required to work the boiler up to its capacity, the products of combustion pass through the combustion space under the boiler and through the tubes at so high a speed that they pass into the chimney at a temperature too high for the greatest efficiency of evaporation. This high velocity of the products of combustion can be avoided by the use of forced draft, the resistance of the fuel bed being overcome by the pressure produced under it, while the conditions on top can be kept adjusted for the most economical working. The forced draft can be obtained either by the use of a fan blower or by means of a steam jet blower, and the current of air may be delivered into the closed ash pit of an ordinary setting, or through special, hollow, perforated grate bars. When a steam jet is used the steam is superheated by carrying the pipe through which it flows along the bottom of the boiler where it is exposed to the hot products of combustion. When a fan is used the air is often preheated by being made to pass through flues in the side walls and bridge wall.

A good form of steam jet blower installation is made by the Parsons Manufacturing Company. In this the steam pipe is carried along the bottom of the boiler to the back of the setting and the air is delivered from the back under the grate just in front of the bridge wall, through which the air pipe passes. The grate is made of iron plates perforated with a number of small holes.

The "White" grate is a type of the installations using a fan blower and hollow, perforated grate bars, the blast passing into the grate bars from a header with which they are connected.

Except for the special form of grate used and the provision of forced draft, the furnaces and settings are practically the same as those ordinarily employed for horizontal return tubular boilers.

128. Boilers are often rated as being of so many horse-power. What is the meaning of the term "horse-power" when used in this connection? What is the meaning of the same term when applied to steam engines?

Ans. The term "horse-power" as applied to the rating of boilers is used in two different ways; either as an absolute unit, by which to measure the rate at which the boiler will work, or as an approximate measure of the capacity of the boiler, to be applied in buying, selling, or describing it for trade purposes.

The trade or commercial horse-power is determined according to certain arbitrary assumptions from the dimensions of the boiler, the extent of the heating surface being usually employed for this rating on a basis of 12 sq. ft. of such surface for each horse-power. Thus, a boiler having a heating surface of 1,200 sq. ft. would be ordinarily rated as being of 100 horse-power. The practice in this respect is, however, not uniform, and it is necessary when comparing different ratings of boiler capacity, especially in passing upon proposals for the supply of new boilers, to know upon what rule each rating is based. A rough-and-ready rule for approximating the commercial horse-power of either tubular or water tube boilers has been given by the "Engineering News" as follows: "Multiply the number of tubes by their length in feet and the product so obtained by the diameter of the tube in inches, then divide the final product by 50, and the quotient so obtained will be the horse-power of the boiler." The commercial horse-power is also sometimes determined from the grate surface, from one-quarter to one-half of a square foot being allowed per horse-power according to the kind of fuel used and its quality.

When used in engineering work for an accurate measure of the rate at which a boiler will do work, the term "horse-power" has been defined by a committee of the American Society of Mechanical Engineers as meaning "an evaporation of 30 lb. of water per hour from a feed-water temperature of 100° F. into steam at 70 lb. gauge pressure, which shall be considered equal to 34½ units of evaporation, that is to 34½ lb. of water evaporated from a feed-water temperature of 212° F. into steam at the same temperature. A boiler should only be rated at the power which it is capable of developing with easy firing, moderate draft and ordinary fuel while exhibiting good economy, and should be capable of developing at least one-third more than its rated power to meet emergencies."

When applied to steam engines, the term "horse-power" is used to indicate the rate at which mechanical work is done, and denotes the performance of work at the rate of 550 foot pounds per second, or 33,000 foot pounds per minute. A foot pound of work is the work done in raising a weight of 1 lb. through a height of 1 ft., or of overcoming a resistance of 1 lb. through a distance of 1 ft., or of overcoming any smaller or larger resistance through a correspondingly greater or less space.

129. How can the weight of water evaporated per pound of fuel by a boiler under ordinary working conditions be determined approximately?

Ans. An approximate determination of the weight of water evaporated per pound of fuel consumed by a boiler, under ordinary working conditions, can be made by measuring the water fed to the boiler during any period of regular operation, and weighing the fuel used during the same period. The water line should be at the same height and the fire in practically the same condition at the end of this period as they were at the beginning.

An easy way of measuring the water fed to the boiler is to put a water meter on the feed water pipe, between the feed pump and the feed water heater, if one is used, so that all the water put into the boiler, and only the water so used, passes through the meter. The weight of a cubic foot of the water used at its ordinary temperature having been obtained by drawing off and weighing a sufficient number of samples to get a fair average, the volume of water used, as shown by the meter readings, can then be multiplied by this weight of unit volume to find the weight of water used. This total weight, divided by the weight of fuel consumed, gives the weight of water evaporated per pound of fuel.

If the feed water connections between the meter and the boiler are kept tight and the meter kept correct by periodical testing, this method will give fairly accurate results. It is useful for determining which one of several fuels, purchased at different prices, is really the most economical to use, without going to the expense of making a number of complete tests in which every precaution is taken to insure extreme accuracy. When kept in use continuously, the meter being read every day at a regular time, and approximately the same amount of fuel kept in stock, it is also valuable as a check upon the quality of the work of the fireman. In this way alone it will more than repay the slight cost of the extra meter and connections, and the time required for making the necessary observations and calculations.

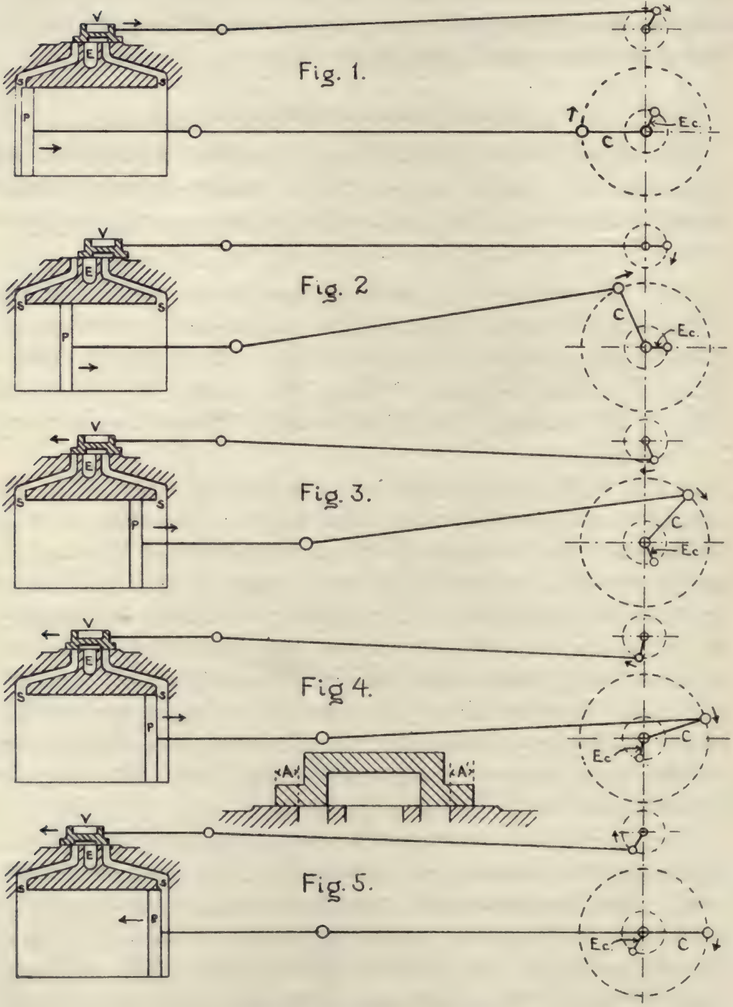
Engines and Exhausters.

130. Give a brief description, illustrated by sketches, of the action of a simple single cylinder steam engine, explaining especially the setting and action of the eccentric and slide valve.

Ans. By referring to the diagrams on the cut, the action of the single cylinder steam engine can be readily understood. These diagrams show in outline cylinder, piston, ports, crank, eccentric and slide valve, P being the piston, SS the steam ports, E the exhaust port, C the crank, Ec the eccentric and V the slide valve.

In Fig. 1 the piston is shown in the position occupied at the completion of a stroke from right to left. The slide valve is so situated with reference to the ports that steam is being admitted through the left hand steam port to that portion of the cylinder on the left of the piston ; while that on the right is open to the exhaust through the right hand steam port, the exhaust cavity of the valve and the exhaust port. The entering steam therefore forces the piston to the right, and with it moves the piston rod, connecting rod, crank and shaft, from which latter, motion is imparted to the valve through the eccentric, eccentric rod and valve stem.

The valve at first travels in the same direction as the piston, increasing the amount of opening for admission of steam, until, when the piston has traversed about one-quarter of its stroke, the full width of the port is opened, as shown in Fig. 2. The direction of the motion of the valve then changes, and it travels in the opposite direction to the piston, gradually decreasing the opening for steam, until, at the position shown in Fig. 3, the admission of steam is entirely cut off. The steam already in the left hand end of the cylinder continues to



STEAM ENGINE DIAGRAMS.

drive the piston forward, as its pressure is greater than the pressure in the right hand end, which is still open to the exhaust. From this point of the stroke the steam expands, still doing work, until the continued motion of the valve in a direction opposite to that of the piston again changes the conditions by closing the right hand steam port and putting the left hand one into communication with the exhaust port as shown in Fig. 4. As soon as this occurs, compression begins to take place on the right hand side of the piston, and the pressure on the left is lowered by the escape of the expanded steam to the air through the exhaust, the combined action gradually checking the motion of the piston now maintained solely by the inertia of the moving parts. Finally, just before the piston comes to a stop at the end of the stroke, the continued travel of the valve to the left begins to open the right hand steam port, and steam is admitted to the right of the cylinder in readiness for the return stroke from right to left. Fig. 5 shows the relative positions and direction of motion of valve and piston at the beginning of this stroke, during which the sequence of events is the same as that described above, the directions being reversed and left substituted for right and vice versa.

Before considering the setting of eccentric and valve, we will define the terms used in connection with these parts of an engine. In the section of slide valve and valve face given in the cut, the valve is shown in the position it occupies at half travel. The length A and A^1, by which it overlaps each steam port externally, is called the "outside lap" or simply the "lap." If the valve overlaps the port on the exhaust side, the length of such lap is called "inside lap." The valve shown has no inside lap. "Outside lead" is the width of the opening of the steam port for the admission of steam at the beginning of the stroke. "Inside lead" is the width of the opening of the steam port on the exhaust side at the beginning of the stroke. "Angular advance," or the advance of the eccentric, is the angle formed by the centre line of the eccentric at half travel, and the position of the same line when the piston is at the commencement of its stroke. "Linear advance," or the advance of the valve, is the distance that the valve has travelled beyond the middle position when the piston is at the commencement of its stroke. The "travel" of the valve is the distance passed through in going from one extreme position to the other.

The distribution of steam during the stroke of the piston, that is, the points at which admission begins and cut-off takes place, and at which compression and exhaust commence, is regulated by varying the lap, lead and travel of the valve. For the class of engine we are considering, this distribution, once determined for any particular engine, cannot be varied. Having been so determined, the three elements named above are adjusted to give the required result, and the valve and eccentric designed accordingly.

To set valve and eccentric, the engine is set exactly on the centre. To do this the brasses are set up until there is no looseness nor play in the bearings. A line is "scribed" on the guides and the cross head in such a manner as to permit of their being brought back at any time to precisely the same relative position, but with the crank the same distance above and below the centre. Marks are also made on the crank disc, or the wheel, so that the arc traversed by a point on either, during the motion of the cross head from the marked position back to it again, can be exactly measured. This arc is then bisected, and the wheel or disc being moved back through the half-arc, the engine is on the centre.

The eccentric is then set in position at the determined angle with the crank, and the valve secured on the stem with the determined "lead." Turning the wheel a half revolution to bring the engine on the opposite centre, the "lead" is again measured, and if not exactly the same as at the other end, the valve is readjusted on its stem until the "lead" is equal at both ends. This done, the eccentric is moved until the amount of the "lead" is right as determined, and the setting is complete.

131. What is the principal point to be borne in mind in running the exhaust pipe for a non-condensing steam engine?

Ans. The principal point to be borne in mind in running the exhaust pipe of a non-condensing steam engine, or, for that matter, any other type of engine, is that the steam should be allowed to escape from the cylinder of the engine with as little resistance as possible to its flow, since whatever resistance is encountered throws just so much back pressure upon the piston of the engine and reduces the effective work done by increasing the amount of useless work. To avoid resistance the exhaust pipe should be made ample in size, and no sharp bends should be allowed—long turn elbows, or, better yet, pieces of pipe bent to long curves, being used for all turns which it is necessary to have. While these are very simple precautions they are very often overlooked, although the cost of the amount of steam saved by reducing the back pressure to a minimum will soon pay for all the extra expense incurred in running the exhaust pipe properly.

132. How would you proceed to determine the efficiency of the steam engine as a machine, and what is an average for this efficiency in small engines such as are commonly used in gas works?

Ans. To determine the efficiency of the steam engine as a machine, it is necessary to ascertain the amount of power exerted on the piston of the engine by the steam used in the cylinder, and the amount of power available at the engine shaft. The latter amount divided by the former gives the efficiency of the engine as a machine, which efficiency is always less than 1, and in the case of small engines is usually between 0.75 and 0.85.

To obtain the power exerted on the piston by the steam used, the mean effective pressure of the steam in pounds is calculated from a series of Indicator diagrams taken at equal, short intervals during the test, which should be of sufficient duration to insure the securing of average results. The quotient obtained by dividing the sum of the mean effective pressures shown on all the diagrams by the number of diagrams is the pressure to be used in the calculation. There is also required for computing the power exerted in the cylinder, the net area of the piston in square inches and the mean piston speed in feet; the latter being obtained by multiplying the length of the stroke in feet by 2 (since there are two strokes to each revolution) and the product so given by the mean number of revolutions per minute determined by frequent countings during the test. The final product resulting from the continued multiplication of the mean effective pressure, the net area of the piston and the piston speed is the work done per minute in foot pounds, which divided by 33,000 gives the horse-power obtained in the cylinder, that is the indicated horse-power.

The available power at the engine shaft is usually obtained by the use of some form of friction brake. A simple form is made of two blocks of wood hollowed out to fit a portion of the circumference of the pulley on opposite sides of which they are to be clamped. Two bolts passing through both blocks, one on each side of the pulley, complete the brake proper. The pressure, and therefore the amount of friction, is adjusted by drawing up or loosening the nuts on these bolts. To measure the power one end of a wooden beam is fastened to one of the blocks by the same bolts that clamp the blocks. The downward pull due to the weight of the overhanging end of the beam should be exactly counterbalanced by weights suspended from the short end on the opposite side of the shaft. At the extreme point of the long arm is attached a spring balance. Stops are provided above and below the beam to limit its possible motion.

The engine, being started, is slowly brought to full speed, the bolts on the brake being drawn up gradually, until the joint effect of the friction when the engine is at the desired speed and the pull of the balance in the opposite direction is such as to keep the beam arm in equilibrium free of the stops and in the space between them. The amount of the pull of the balance, as obtained by averaging a number of readings made at equal intervals during the test, is the force in pounds which is exerted, during each revolution, through a distance equal to the circumference of a circle with a radius equal to the effective length of the brake arm. The distance through which the force will be exerted in a minute will be equal to this circumference multiplied by the mean number of revolutions per minute. If, therefore, we represent the effective length of the brake arm in feet by L, the pull in pounds on the end of the arm by W, and the mean number of revolutions per minute by N, the circumference of the circle will be $2\pi L$ ($\pi=3.1416$) and the power available per minute will be $2\pi L \times N \times W$, and the horse-power at the engine shaft, that is, the effective or brake horse-power will be $\frac{2\pi LNW}{33{,}000}$

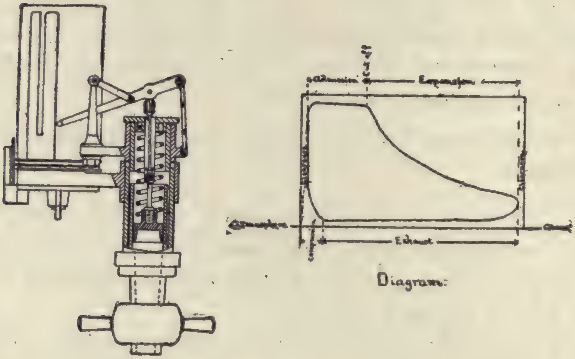
As previously stated the quotient obtained by dividing this effective horse-power by the indicated horse-power is the efficiency of the engine as a machine.

133. Describe an Indicator and its use in connection with a steam engine.

Ans. An Indicator is an instrument used to measure and register continuously and simultaneously the conditions of pressure and volume of the working fluid existing in the cylinder of a heat engine at work.

As now made, the indicator consists of a cylinder containing a piston working against a spring. Attached to the piston is a rod with its head so connected to a lever that the motion of the piston is multiplied and transferred to a pencil holder, the path of which is kept parallel to that of the piston by means of some form of parallel motion. A pencil placed in this holder can be brought into contact with a sheet of paper wrapped around a drum made to turn about its axis with a reciprocating motion by a cord wound around its base and connected to the proper point on a "pantagraph," or other form of "reducing motion," attached to and moving with the cross-head of the engine; which cord works in opposition to a spring fastened to the drum.

Suitable fittings, including a steam cock, are provided for making a connection between the indicator cylinder and the engine cylinder. When this connection has been made and the cock opened the pressure of the working fluid in the engine cylinder is communicated to the bottom of the indicator piston, causing both it and the pencil to rise and fall with the rise and fall of pressure in the engine cylinder. At the same time the cord on the drum being connected to the reducing motion, the drum and paper rotate back and forth as the engine piston moves. Then by pressing the pencil lightly against the paper a diagram is obtained showing all the varying conditions of pressure and volume of the working fluid in the cylinder as they exist throughout the period of contact, which is usually limited, as nearly as possible, to one revolution of the engine. Each diagram or "Indicator-card" gives a record of the conditions, on one side of the piston only, during one revolution of the shaft, so a pair of cards taken at the same time and one from each side of the piston are necessary to furnish a complete record for one revolution of the engine. In these diagrams, vertical distances above or below a horizontal line traced on the paper when the piston is at its normal position and free from pressure represent pressures in pounds per square inch above or below atmospheric pressure on a scale varying with the strength of the spring employed; and horizontal distances represent the travel of the engine piston on a scale determined by the proportions of the reducing motion employed.



INDICATOR.

To insure the accuracy of the diagrams it is necessary that any given indicator should be tested and standardized before being used. The principal sources of error, apart from inaccurate springs, are the inertia and friction of the moving parts, the friction of the pencil on the paper, and the elasticity of the cord used to impart motion to the drum. To overcome inertia the moving parts are made as light as possible. The friction of the piston is reduced to a minimum by making it fit loosely in the cylinder, the best makes showing an observable leak between piston and cylinder under high pressure; openings being left in the upper part of the cylinder sufficiently large to prevent this leak from giving rise to any excess of pressure above the piston. The friction of pencil on paper is reduced to a minimum by the use of a very hard lead pencil, or one of soft metal brought to a sharp point, and a highly glazed paper so that a light, steady pressure will produce a very fine but entirely distinct line. The cord should always be stretched by a heavy weight before being used, but even when this is done will retain some elasticity, and a fine steel wire is to be preferred. The effect of this elasticity can be reduced by proportioning the strength of the spring in the base of the drum to the inertia of the drum so as to make the pull on the cord practically constant.

The spring against which the piston works should be tested by connecting the indicator with the spring in place, to a steam reservoir, in such a manner that the pressure can be held at any desired point on both the indicator and a correct gauge long enough to enable readings of each to be taken deliberately and accurately. These readings should agree when the spring is hot, since in practice the spring will be hot when used. The springs should be so made and attached that they will not, when under pressure, throw the piston out of line and cramp it in the cylinder.

According to Dr. R. H. Thurston the best indicator is that "which has proportionally the largest and lightest piston, the stiffest and lightest springs, the least friction of moving parts, the most perfect pencil mechanism, the most accurate and constant scale of pressures, the most perfect adjustment of drum-spring, and the lightest moving parts generally," but in no instrument, however well-made, is it found possible to "wholly eliminate the influences of inertia of moving parts, friction of joints and guides, if the latter be used, and of piston or pencil, or the effects of variation of spring tension on the motion of paper cylinder and card. Standardization is the process of detecting and measuring such errors as are observable in the action of the apparatus, and the determination of their influence on the indications obtained by its use."

The connection between indicator and engine cylinder should be sufficiently large and free from bends and angles to insure the transfer of the pressure in the cylinder to the indicator without loss. The hole in the cylinder should be so located that it will not be covered by the piston at the end of the stroke, and that the steam entering the cylinder by the steam port does not blow across it and thus affect the pressure in the pipe leading from it.

Again quoting Dr. R. H. Thurston, "Manual of the Steam Engine," "Indicator-diagrams taken under proper conditions and with good instruments, are diagrams of energy on which the ordinates measure the varying pressures in the cylinder, corresponding to the positions of the piston as measured off by the simultaneous abscissas of the diagram; while the area represents the work done by the steam on the piston of the engine" and by their means "it becomes possible to ascertain the nature and cause of almost every defect in the distribution of pressures and volumes of the working fluid, as in the adjustment of the valve-motion, and the size or proportions of steam-passages, or of the connecting pipes. The power exerted by the steam is easily measurable. These several points may be summarized thus:

(1) Gross power exerted by the steam.

(2) Net power of the steam, and equivalent net power of the engine.

(3) Resistance of unloaded engine.

(4) Net power of the engine.

(5) Details of various wastes of power, as by wire-drawing, back-pressure, etc.

(6) Valve-adjustments.

(7) Effectiveness of valve-gearing.

(8) Adequacy of sizes of port.

(9) Quantity of steam present at any point in the stroke.

(10) Feed-water demanded, exclusive of that wasted by cylinder condensation.

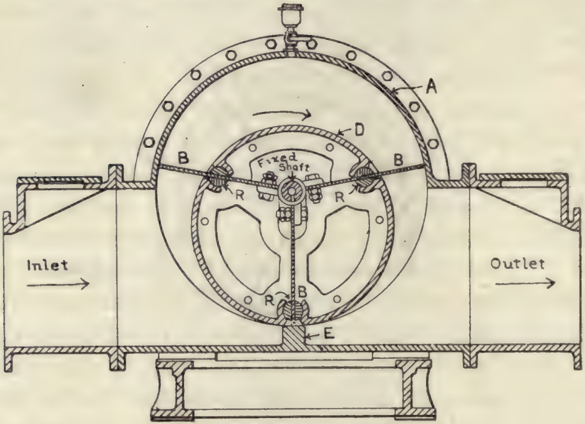
(11) With a boiler-trial, the actual expenditure of steam, fuel and money, for a given amount of power; and wastes by leakage and condensation.

"Of these, the principal are only determined by careful computation, employing as data the quantities graphically measured on the indicator-diagram; others are at once seen by the practised eye, demanding only an inspection of the figures shown on the card. An engine well adapted to its purpose, a perfect engine in the engineer's sense, will usually exhibit an early induction; wide port-opening; an admission-line closely approaching boiler-pressure, and nearly or quite horizontal; a sharp cut-off; an expansion-line closely approaching the common, or equilateral, hyperbola in form; a somewhat early and a prompt release or exhaust; a low and uniform back-pressure, and a compression carried up well toward initial pressure. These effects are obtained by giving some steam and exhaust lead—greater as speeds and pressures are higher, having good area of ports, securing quick action of the expansion-valve, and a well-adjusted closure of the exhaust-valve. Any departure from these conditions is ordinarily to be taken as evidence of defective construction or adjustment."

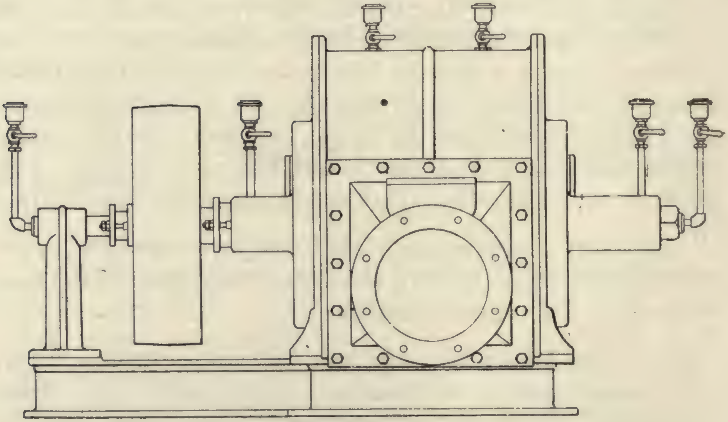
The cut shows an indicator partly in section and also an imaginary diagram. The student, of course, should study up the subject more fully before relying upon his ability to use an indicator. Good books for this purpose are "A Hand Book of Engine and Boiler Trials, and the Use of the Indicator and the Prony Brake," by Dr. R. H. Thurston, and "Practical Instructions for Using the Steam Engine Indicator," published by the Crosby Steam Gauge and Valve Co., Boston, Mass.

134. Give a description, illustrated with sketches, of the construction and action of a Mackenzie exhauster. Of a Root exhauster. Of a Fan exhauster.

Ans. The Mackenzie exhauster belongs to the class of so-called rotary positive exhausters. An elevation and vertical cross section are shown on the cut. A is a cast-iron case, the general shape of which is cylindrical, with inlet and outlet openings as shown. The moving parts consist of the hollow drum D, open at both ends, the blades B, B, B, and the rolls R, R, R. The length of the drum is such that there is just clearance at each end between it and the inside of the projections of the case (shown on the elevation), the inside diameter of these projections being only a small fraction of an inch larger than that of the drum. This is set with its centre below that of the case, and its circumference tangent at the bottom to the rib E, running along the bottom of the case. It is rotated about its centre by means of a hollow shaft projecting from one end, which shaft is turned by a belt pulley or direct from an engine on the same bed plate as the exhauster. Between the pulley and the drum the shaft is supported by a



Cross Section.



Elevation

MACKENZIE EXHAUSTER.

bearing cast on the case, and a similar shaft projects from the other end of the drum to support it by means of another bearing on that end of the case.

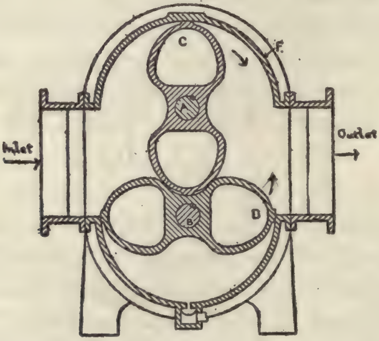
The blades B, B, B, are free to rotate around a fixed shaft, the axis of which coincides with the axis of the main cylinder of the case, and are of such size that the outer edges just clear the inner circumference of the case on top and the rib E on the bottom, while the ends just clear the inside of the end plates of the case. The shaft around which the blades rotate is bent down at each end, beyond the blades, and passes through the hollow shaft of the drum to an outboard bearing on the pulley end, while at the other end it projects just beyond the outside of the bearing in the case.

As the drum rotates, its circumference, at the points where the blades pass through it, is continually changing its position relatively to the blades, and the function of the rolls R, R, R, is to permit of a continual sliding motion at these points by rocking back and forth, in their bearings in the drum, so as to keep the slots through which the blades pass always in line with the blades.

The action of the exhauster is as follows: The drum D, being rotated in the direction of the arrow, carries the blades B, B, B, with it, and these blades being practically in contact with the circumference and ends of the case, force the gas ahead of them and thus pass it from inlet to outlet. As the drum is practically in contact with the rib, E, the gas driven forward on top cannot pass back on the bottom and must go out by the outlet.

By a study of the cross section it will be seen that in this, as in all similar forms of rotary exhausters, the space on the one side is continually increasing in volume, while that on the other is continually decreasing, thus drawing in gas on the one side, the inlet, and forcing it out on the other side, the outlet.

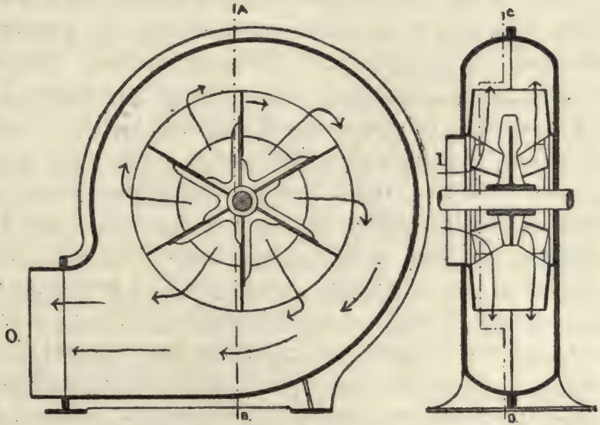
The Root exhauster is also a rotary positive exhauster. A vertical cross section is shown on the cut. F is a cast-iron case consisting of two half cylinders, of equal diameter, separated by a rectangular prism, and with flat ends. The moving parts consist of the two impellers, C and D, keyed respectively to the shafts, A and B, and so set in the case that the axes of the corresponding shaft, impeller and half cylinder coincide. The impellers are so shaped that as they rotate each is always in contact, at some point, with the cylindrical portions of the case, and at the same time in contact with the other, while the ends are practically in contact with the ends of the case. The shafts are supported by bearings on the case, and connected with each other at each end by two gear wheels, one on each shaft, of the same diameter, and with an equal number of teeth, so that the relative position of the impellers is always the same, at the same point in any revolution. The lower shaft is extended at one end and provided with a belt pulley, or connected direct to an engine on the same bed plate as the exhauster.



CROSS SECTION OF ROOT EXHAUSTER.

The action is as follows: Motion being imparted to shaft B, is transmitted through the gear wheels to shaft A, causing the two impellers to rotate, as shown by the arrows, and by the continual increase in volume of the space on the inlet side and decrease in volume of that on the outlet side, to draw the gas from the inlet and force it through the outlet, the contact between the impellers preventing the gas from passing back through the middle.

The Fan exhauster, although its moving parts rotate, is not included among the so-called rotary exhausters, this term being applied only to exhausters which impart motion to the gas by the alternate increase and decrease in the size of practically gas-tight spaces. The Fan exhauster consists of a fan wheel, composed of a number of blades extending radially from its axis and presenting practically flat surfaces to the air as they revolve, enclosed in a case of much larger radius than the wheel. The wheel being revolved at a high speed, sets in motion the gas within it, and by the centrifugal force so generated, delivers this gas tangentially at its outer circumference. There is thus formed a partial vacuum at the centre of the wheel, which draws more gas through the axial inlet to be delivered at the circumference and through the outlet, which can be placed in any position on the circumference of the case.



Section on CD. Section on AB.

FAN EXHAUSTER.

The cut shows two sections of a Fan exhauster. The fan wheel being revolved in the direction shown, draws gas in through the inlet I and delivers it at the circumference of the wheel, from which it is guided by the case, to the outlet O, which, in this instance, is placed at the bottom of the case. The direction of travel of the gas is shown by the arrows.

135. What horse-power is required for the actual work of pumping the gas by an exhauster handling 17,000 cubic feet

of gas per hour with an inlet pressure of $\frac{1}{10}$ in. and an outlet pressure of 12 in. ?

Ans. The term "horse-power" as used to indicate the rate at which mechanical work is done denotes the performance of 33,000 foot pounds of work per minute, that is, the raising of a weight of 33,000 lb. through a height of one foot, or the overcoming of a resistance of 33,000 lb. through a space of one foot, or of any smaller resistance through a correspondingly greater space per minute. The horse-power required to pump gas can therefore be calculated by dividing the product of the resistance overcome and the space through which it is overcome in a minute, by 33,000, the resistance being measured in pounds per square foot and the space in feet. The resistance is determined by the net pressure against which the exhauster is working, that is, by the difference between the pressure at the outlet and that at the inlet of the exhauster. The space can be taken as the number of cubic feet of gas pumped in a minute without any reference to the actual velocity with which the gas passes through the outlet pipe, since with a given outlet pressure the total resistance against which the exhauster is working varies directly as the area of the outlet pipe, while the velocity of the gas, or the space passed through in the unit of time varies, when the same quantity is pumped per minute, inversely as the area of this outlet pipe, and therefore the product of the total resistance and the space passed through will always be equal to the product obtained by multiplying the resistance per square foot by the number of cubic feet of gas pumped in the unit of time. The pressure is usually given in terms of the height, in inches, of the column of water which it will balance, and to convert this to pounds per square foot it is necessary to multiply it by the weight of a column of water one square foot in area and one inch high. A cubic foot of water weighs 62.5 lb., so a column of water 12 in. high exerts a pressure of 62.5 lb. per square foot, and a column 1 in. high will exert a pressure of $62.5 \div 12 = 5.2$ lb. per square foot.

The horse-power required for the actual work of pumping the gas can therefore be determined by multiplying the number of cubic feet pumped per minute by the product obtained by multiplying the net pressure in inches of water by 5.2 (which gives the pressure in pounds per square foot against which the exhauster is working) and dividing the final product by 33,000. Putting this rule into the shape of a formula we have:

$$\text{H. P.} = \frac{VH \times 5.2}{33{,}000}, \text{ in which}$$

V = number of cubic feet of gas pumped per minute, and

H = the difference between the outlet and inlet pressures in inches of water.

In the present problem

$$V = \frac{17000}{60} = 283.33, \text{ and}$$

$$H = 12 \text{ in.} - 0.1 \text{ in.} = 11.9 \text{ in., so}$$

$$\text{H. P.} = \frac{283.33 \times 11.9 \times 5.2}{33000} = \frac{283.33 \times 61.88}{33000} = \frac{17532.46}{33000}$$

= 0.531, and therefore the horse-power required for pumping the gas, without taking into consideration the friction of the exhauster, or any other losses of power in the machinery, is 0.531 horse-power.

From the information obtained by a series of tests made on exhausters pumping gas into outlying holders, in which tests the amount of gas pumped, the pressure against which it was pumped and the horse-power developed in the engines doing the work were all determined, Mr. Geo. J. Roberts works out the following formula to be used in determining the total horse-power required in any given case when the gas is to be handled with an exhauster of the Wilbraham type.

$$\text{H. P.} = 0.00511 \times H \times V, \text{ in which}$$

H = the net pressure in inches pumped against, and

V = thousands of cubic feet pumped per hour.

Substituting the values of H and V in the present problem we have:

$$\text{H. P.} = 0.00511 \times 11.9 \times 17 = 1.03.$$

So that the total horse-power required according to this formula is nearly double that required for pumping the gas. Or, in other words, the efficiency of the engine and exhauster when working at this rate is only about 50%.

136. Should the speed of an exhauster used for the purpose of relieving the retorts of a coal gas plant from the pressure thrown by the rest of the apparatus be governed in the same way as the speed of an exhauster used for drawing gas from the relief holder of a carburetted water gas plant and forcing it through the rest of the apparatus? Give the reasons for your answer.

Ans. The speed of a coal gas exhauster should not be governed in the same way as that of an exhauster drawing gas from the relief holder of a carburetted water gas plant, since the two exhausters perform entirely different duties.

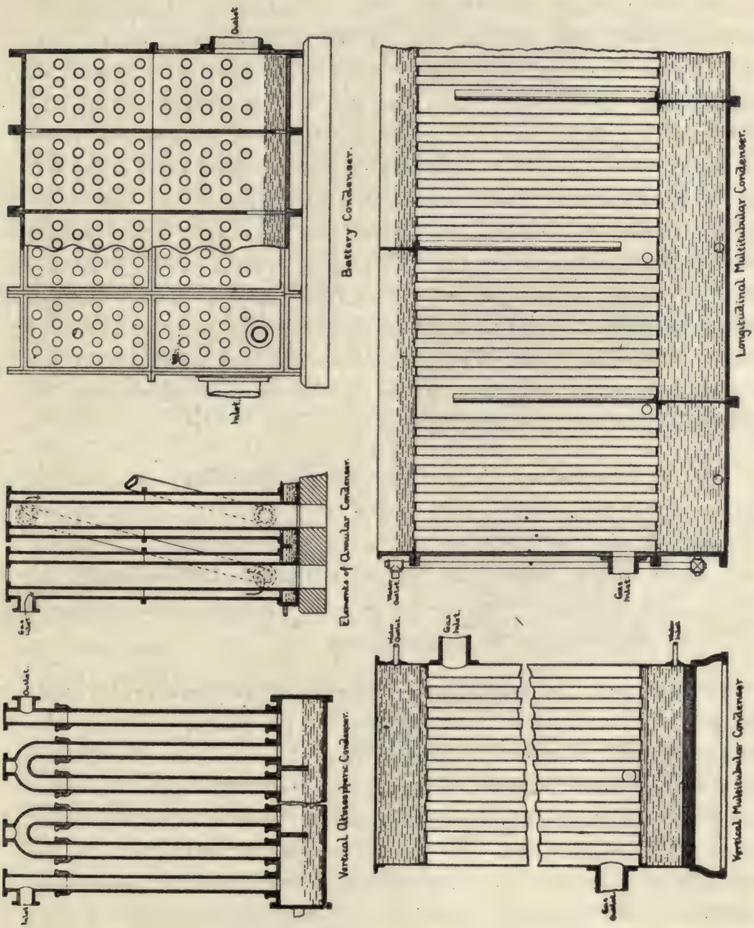
That of the coal gas exhauster is to relieve the retorts of the pressure thrown by the rest of the apparatus and to maintain a constant low pressure in the hydraulic main. To do this the gas must be drawn away at exactly the rate at which it is being made at any instant, and as the gas is not made at a uniform rate it is impossible for the coal gas exhauster to run at a uniform speed if it is to perform its duty properly. Its speed must therefore be governed in such a way as to be increased as the rate at which the gas is made increases, and to be decreased as the rate at which gas is made decreases. In this way the pressure at the inlet of the exhauster, and consequently in the hydraulic main, is kept constant.

The sole object of the exhauster in a carburetted water gas plant is to force the gas through the purifiers and station meters into the holders, the pressure thrown by the relief holder being, as a rule, insufficient for this work. Since the relief holder compensates for the inequalities in the rate of make, this exhauster can be, and is, run at a uniform speed such that it will handle the gas at a rate equal to the average rate of make, and it must therefore be governed in such a way as to maintain a constant speed, this being varied from time to time to suit the requirements of production.

Condensers.

137. Give a description, illustrated with sketches, of one or more forms of the condensers used for cooling illuminating gas during the process of manufacture.

Ans. One of the earliest and simplest forms of condensers used for cooling illuminating gas during the process of manufacture is composed of ordinary cast iron pipes inclined at a small angle to the horizontal, and fastened to the side of a


Outlet.
Inlet.
Battery Condenser.
Longitudinal Multitubular Condenser.
Elements of Annular Condenser.
Vertical Atmosphere Condenser.
Vertical Multitubular Condenser.
Outlet.
Inlet.

CONDENSERS.

wall in such a way that the pipes zigzag back and forth until the ground line is reached. The gas passes through these pipes and radiates its heat into the air, until it is cooled down to the temperature of the atmosphere. This form has been elaborated into what is known as the flat screw condenser, in which the inclined pipes are in double tiers and are mounted on frames or standards.

Another simple form of atmospheric condenser is composed of vertical pipes mounted on a cast iron box. The pipes are connected together at the top, in pairs, by return bends provided with cleaning holes, and in the box, partitions sealed in the liquids condensed from the gas are placed between the pipes joined together by the bends, there being one partition for each pair of pipes. The box is thus divided into compartments into each of which open two pipes which are not connected together at the top. At each end is a single pipe opening into a compartment of the box, into which also opens one pipe of a set of two connected at the top. By this arrangement the gas entering at the top of the single pipe at one end passes down into the box and then up and down the pipes alternately until it passes out at the top of the single pipe at the other end of the apparatus.

This condenser has also been elaborated from the simple form containing only a single row of pipes into a condenser containing several parallel rows, the top connection between the pipes being made by properly placed hoods sealed in liquor, the box and partitions at the bottom being substantially the same as in the simple form.

Another vertical atmospheric condenser is the annular condenser, which consists of a series of large pipes, through the centre of each of which passes a smaller pipe, open to the air at both top and bottom. The gas travels through the annular space between the pipes and imparts its heat to a current of air induced through the centre as well as to the air on the outside of the pipe, the radiating surface being thus nearly doubled. The annular space in one pipe is connected to that of the next by a smaller outside pipe, or pipes, which conveys the gas from the top of one space to the bottom of the next, or vice versa, or else this space is divided into two parts by vertical ribs extending almost the whole length of the pipes, so that the gas passes up on one side and down on the other, and the spaces are connected by short pipes running from the bottom of one to the bottom of the next. If the ribs are arranged to make the gas travel first down and then up, the spaces are connected together at the top instead of at the bottom.

Still another form of atmospheric condenser is that known as the battery condenser. This is an oblong box from 2 ft. to 5 ft. wide, 10 ft. to 18 ft. high and of varying length. It is divided internally into compartments by means of partitions, leaving openings alternately at the top and bottom, so that the gas entering at the bottom of the first compartment is forced to travel up in this and down in the next until it passes out at the bottom of the last compartment. Tubes 2 in. in diameter, with both ends open to the air, are run horizontally across the compartments, and the currents of air passing through these assist in cooling the gas. In both the annular and the battery condensers arrangements are made for regulating, in one case the size, and in the other the number, of the openings for the admission of air, in accordance with the temperature of the air and gas at different times.

Atmospheric condensers of one or another of these types are practically the only condensers used in England, but in this country it is considered better practice to employ condensers in which the cooling of the gas is effected by imparting its heat to water. The usual form of such condensers is the ordinary vertical multitubular type. This consists of a cylindrical wrought iron or steel shell from 2 ft. to 10 ft. in diameter, and from 12 ft. to 20 ft. high, closed at the bottom by a cast iron base plate and at the top by a plate of the same material as the shell. It is divided into one gas and two water compartments, by two horizontal tube sheets, one placed from 18 in. to 30 in. from the top and the other the same distance from the bottom. In these sheets are expanded a number of tubes, which run through the large gas compartment and open into the smaller water compartments at the top and bottom. Water under pressure being run into the bottom compartment rises through the tubes to the top compartment, from which it overflows. The hot gas is admitted at the top of the gas compartment and passes down around the tubes and out at the bottom, becoming cooled as it descends. In this way the hot gas comes in contact first with the part of the tube containing hot water, and then, as it descends, with the parts containing cooler and cooler water, so that the cooling of the gas should take place gradually. It is found, however, that it is a very difficult matter to regulate the water supply in this form of condenser, so as to both cool the gas thoroughly and at the same time prevent the cooling from taking place suddenly in a space extending over not more than one-quarter to one-third the total height of the condenser.

Sometimes in works making over 500,000 cubic feet per day there is used a rectangular multitubular condenser made not more than 12 ft. high, 5 ft. wide, and of a length proportioned to the amount of gas to be handled. The shell of this condenser is made of cast iron plates, and the long gas compartment is divided by vertical transverse partitions with openings alternately at the top and bottom, so that the gas traveling through it passes alternately up and down. The water compartments are also divided by similar partitions so placed in each compartment that the water travels up the tubes which pass through the spaces in which the course of the gas is downwards, and down the tubes passing through the spaces in which the course of the gas is upwards. The cold water is admitted at the end at which the gas passes out, and the hot water passes out at the end at which the gas enters, gas and water thus traveling always in opposite directions. With such a condenser properly proportioned to the amount of gas to be handled, the cooling of the gas can be effected very gradually and the difference in temperature of the gas and water at any given point need not exceed 5° F., and by care can be kept still lower. The first cost of the apparatus is, however, greater than that of vertical condensers rated at the same capacity.

Both of these forms of multitubular condensers are also modified by making the gas pass through the tubes, which are then surrounded by the water.

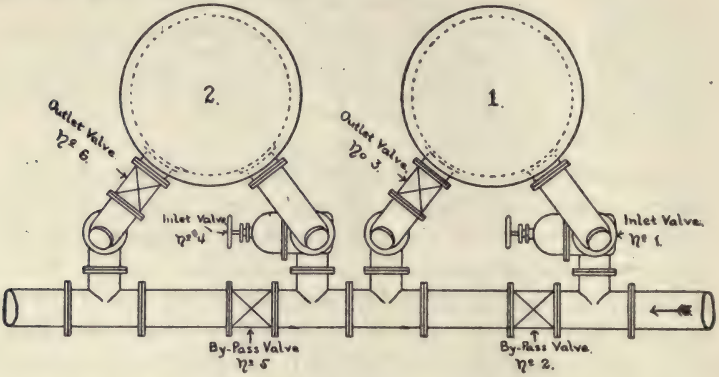
All of the types of condensers described must, of course, be furnished with suitable overflow connections for the condensed liquids, and every condenser should be equipped with two thermometers for ascertaining the temperature of the gas, one at the inlet and one at the outlet, in addition to which water condensers should also be provided with thermometers for determining the temperature of the water as it enters and leaves the apparatus.

In English practice, with atmospheric condensers, 10 square feet of surface, including all exposed pipes from the hydraulic main to the outlet of the condensers, are allowed for each 1,000 cubic feet of gas made per twenty.four hours. In this country it is usual to allow in water tube condensers from 4 to 5 square feet of tube surface for each 1,000 cubic feet of gas made per twenty-four hours, but if it is desired to cool the gas very gradually and not to have more than 5° difference between the temperature of the gas and that of the water at any given point in the condenser, it is necessary to allow from 8 to 10 square feet of tube surface.

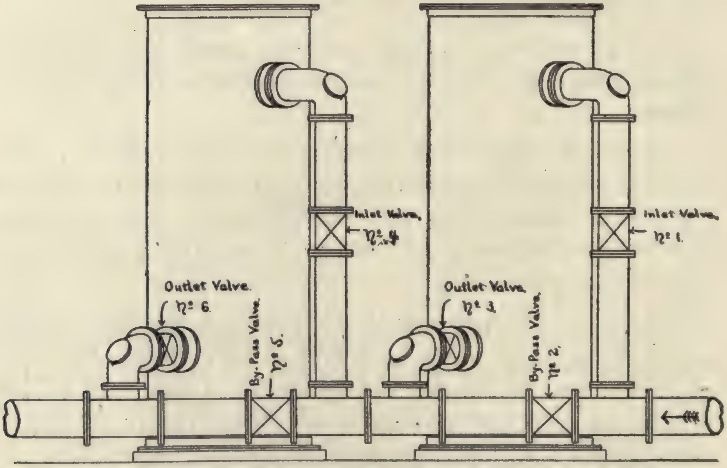
138. What is a by-pass? Give a description, illustrated with sketches, of a by-pass for two vertical, multitubular condensers.

Ans. A by-pass to any part of the apparatus of a gas works is a system of pipes and valves so arranged that by opening one or more valves, and closing others, the gas flowing may be directed either through, or past, that part of the apparatus concerned.

The accompanying cut shows a by-pass for two vertical, multitubular condensers, so arranged that either one or both of them may be thrown out of action at any time without interfering with the working of any of the rest of the apparatus. When both condensers are in action, valves Nos. 1, 3, 4 and 6 are open and valves Nos. 2 and 5 are closed. To throw condenser No. 1 out of action while leaving No. 2 at work, valve No. 2 must be opened and Nos. 1 and 3 closed. Again, starting with both condensers at work, to leave No. 1 in action and throw out No. 2, valve No. 5 must be opened and Nos. 4 and 6 closed. When both condensers are to be thrown out at the same time, valves Nos. 2 and 5 must be opened and Nos. 1, 3, 4 and 6 closed.



By-Pass for Two Vertical Multitubular Condensers.



139. Name, in the order in which the gas should be subjected to them, beginning at the outlet of the hydraulic main, the various steps to be taken in the condensation and purification of coal gas, and state the temperature that should be possessed by the gas at the beginning and end of each step.

Ans. There is a difference of opinion among engineers as to the first step to be taken in the condensation and purification of coal gas as it leaves the hydraulic main. While there is no question that the heavy tar should be removed before the temperature of the gas has fallen below 100° F., it is claimed by some engineers that better and more uniform results are obtained from the tar extractor when the gas reaches it at a uniform temperature between 110° and 120° F. than when its temperature is allowed to be above this, and they therefore advise a preliminary cooling, under control, for the gas, which leaves the hydraulic main at temperatures varying from 140° to 130° F., before it goes into the tar extractor. Other engineers take the gas through the tar extractor with only such cooling as it gets in the pipe through which it passes, and some even go so far as to jacket this pipe to prevent any loss of heat. In most cases of recent construction the preliminary cooling has been adopted and is effected by the use of an annular atmospheric condenser, provided with means for regulating the amount of air flowing through the central opening and, consequently, the amount of cooling suffered by the gas.

As is implied by what is stated above, the next step is the removal of the heavy tar by some form of tar extractor which acts by friction and without affecting the temperature to any appreciable extent, and the gas should enter this piece of apparatus at a temperature not lower than 100° F. and leave it with a loss of not more than two or three degrees.

After passing through the hot tar extractor the gas is ready to be cooled gradually in water condensers by which its temperature should be reduced to 60° F. In cold climates there would not seem to be any objection to, and there might very possibly be an advantage in, cooling below this point, since the gas is certain to be cooled below it in the holders and street mains, and the gradual cooling that can be given in the condensers is less harmful than a sudden cooling later.

After being cooled, the next step is the removal of the ammonia by means of washers or scrubbers, or a combination of the two, the temperature being kept during this process at as near 60° as possible.

The final step in the purification of the gas is the removal of the sulphuretted hydrogen, and, when advisable, also of the carbonic acid, contained in it. This removal can be effected most economically at a temperature of from 100° to 110° F. and the gas should be heated up to this point at the inlet to the purifiers. This heating can be done by steam either allowed to mix with the gas, or, preferably, passed through a coil of pipe in the bottom of the first box in the series.

As will be noticed no mention of the exhauster is made above since it is not, strictly speaking, part of the condensing and purifying apparatus, all of which will work in exactly the same manner and at the same temperatures whether an exhauster is used or not.

140. What are the results sought to be obtained in the condensation of illuminating gas during its manufacture, and what are the precautions to be observed in carrying on this process in order to secure the cooling of the gas to the proper point with the smallest loss of candle power?

Ans. The results which are sought to be obtained in the condensation of illuminating gas are the complete and harmless removal from the gas, in a condition and at points that permit of their being easily handled, of those vapors, the deposition of which, inevitable under conditions certain to be met with as the gas travels through the works and the mains, will cause great annoyance and damage the illuminating power of the gas if not effected at the proper points and in the proper manner. At the same time no vapors should be taken out that the gas can be made to retain with advantage. Condensation is perfect only when the gas leaves the apparatus containing just the amount of hydrocarbon vapors that will fully saturate it at the minimum temperature and maximum pressure to which it is to be subjected in the distributing system.

To secure this result and so secure the cooling of the gas to the proper point with the least loss in candle power, the following precautions must be observed: All heavy tar should be removed from the gas before its temperature has fallen below 100° F. Contact between gas and heavy tar should be reduced to a minimum, and the gas should never be allowed to bubble through tar. The foul main should be protected to prevent any marked drop in the temperature of the gas while passing through it. Sudden chilling of the gas is to be avoided, especially during the last stages of condensation, and the reduction of temperature between the outlet of the hot tar extractor and that of the condensers should be brought about very gradually. The last requirement can be met only by having well-designed condensers of ample capacity, the proper handling of which is secured by keeping a careful watch on the temperature at all points in the apparatus and varying the conditions accordingly.

141. Why is it important that all tar and oily matter should be removed from the gas before it enters the scrubbers and purifiers?

Ans. If the tar and oily matter are not removed from the gas before it enters the scrubbers in a coal gas works, they will coat the material in these vessels with a greasy film, that will prevent the water from being spread out and presented to the gas in thin sheets covering the whole surface of the material, and will thus render the contact between water and gas imperfect with a consequent reduction in the efficiency of the apparatus. If the scrubbers are filled with coke the deposition of the tar will also fill up the pores of the coke and the spaces between the different lumps, and by thus closing up the channels through which the gas has to pass, will cause the scrubbers to throw a high pressure and make it necessary to remove the coke much oftener than would otherwise be the case, increasing in this way, quite considerably, the cost of material and handling.

The presence of tar and oily matter in the gas produces a similar effect in the purifiers. The friction to which the gas is subjected in passing through the purifying material, causes the tar and oil to be deposited, coating the different particles of the material with a film that prevents any contact between them and the gas, and thus renders them incapable of doing any of the work of purification. If either tar or oil is present in sufficient quantity, its deposition makes the material at the bottom of the first purifier moist and soggy, and when in this state it is very difficult for the gas to pass through it, so that it is often necessary to change the purifiers, on account of excessive pressure, before they are foul. This further increases the cost of labor in addition to the increase in cost of both labor and material caused by the material being rendered inefficient. In the case of iron oxide the oily film on the particles prevents revivification as well as purification, the material lying next to the bottom trays being made unfit for further use, the effect extending to a greater or less distance from the bottom according to the amount of tar and oil in the gas.

In addition to the main effects noted above, the coating of the scrubbing and purifying materials with a film of tar and oil, by causing intimate contact between tar and gas, also reduces the candle power of the gas to a slight extent.

142. What is the effect upon gas of the process called condensation?

Ans. "Condensation is that process which, partly by cooling and partly by friction, removes the tar and oily vapors from the gas. Care is taken not to accomplish this too quickly, lest by sudden changes of temperature, some of the hydrocarbons valuable for illuminating purposes are thrown down and the gas thereby impoverished."

Condensation is theoretically perfect only when the gas leaves the apparatus containing just enough hydrocarbon vapor to fully saturate it at the minimum of temperature and maximum of pressure to which it is thereafter to be subjected. This theoretic perfection can be only approximated in practice.

143. How many square feet of radiating surface should be allowed per 1,000 cubic feet of gas to be handled per twenty-four hours in rating the capacity of atmospheric condensers and of multitubular water condensers?

Ans. In England, where atmospheric condensers are much more commonly employed than is the case in this country, a very generally accepted rule for the amount of surface required in such condensers is thus stated in King's Treatise. "Under ordinary circumstances, where an atmospherical condenser is employed, the condensing pipes, measured from the hydraulic main, should have a superficial area of 10 square feet for every 1,000 cubic feet maximum production per diem." Some authorities, however, allow only 5 square feet of area per 1,000 cubic feet per day when the condensing pipes are made of wrought iron. Some calculations made by Mr. W. H. Y. Webber show that under the conditions assumed by him from 3.5 to 4 square feet per 1,000 cubic feet of gas would be sufficient. But in these calculations there is apparently no allowance made for the latent heat of the aqueous vapor condensed out of the gas as the temperature is lowered, and when this allowance is made, the surface required is increased to 5 square feet. As, however, the whole surface must be at its maximum efficiency to obtain this figure, it is safer to take the larger area mentioned above as being the best to adopt in practice.

The area of cooling surface required in multitubular water condensers, where the difference in temperature between the gas and the cooling medium can be regulated at will, depends, naturally, upon what difference is to be maintained. If it is not to exceed 5° F. and the gas is to be cooled gradually from a temperature of 120° F. to one of 60° F., 8 square feet of tube surface will be required for each 1,000 cubic feet of the maximum production per day. But, if it is assumed that it is permissible to allow an extreme difference of 63° F. between the temperature of the gas and that of the water at the gas inlet end of the condenser and an average difference of 36.5° F., as has been done in the case of some condensers of this type designed for the South Metropolitan Gas Company, of London, England, it is only necessary to have 1.71 square feet of water cooled surface and 1.19 square feet of air cooled surface per 1,000 cubic feet of gas per day.

The multitubular condensers made by one of the large manufacturers of gas apparatus in this country are rated at a capacity which allows about 4.2 square feet of tube surface per 1,000 cubic feet of gas per day. If the water is passed through the tubes and the gas outside of them, the shell affords about 1 square foot of air cooled surface in addition to the water surface. When the gas is passed through the tubes there is no air cooled surface except the small amount around the gas spaces at the top and bottom. These condensers will show average differences in temperature between gas and water of over 10° F. and are apt to cool the gas very suddenly at some one point instead of doing it evenly and gradually.

As the weight of authority and experience is still to the effect that sudden and rapid cooling of the gas is detrimental to the securing of good candle power results, it is advisable in designing multitubular condensers to adopt the largest figures for tube surface that are given above and to provide 8 square feet of surface for each 1,000 cubic feet of the rated maximum capacity per day of the condensers.

If both atmospheric and water condensers are used, the area of tube surface in the latter can be reduced in proportion to the area of air surface provided in the former.

Purifiers.

144. How would you determine the area of the purifying boxes required to purify economically any given amount of gas per twenty-four hours?

Ans. As four-box sets of purifiers are, for many good reasons, the most commonly adopted, this answer treats of such sets only.

The proper area to be given purifying boxes in four-box sets, in order that they may purify economically a certain amount of gas, is determined by empirical rules that have been deduced from the results of experience. The rule that is commonly accepted as correct in England is given in the Sixth Edition of Newbigging's Handbook as follows: "Where there is intended to be four purifiers, three always in action, the maximum daily (24 hours) make of gas, expressed in thousands, multiplied by the constant 0.6, will give the superficial area in feet of each purifier." According to this rule there must be provided 60 square feet of area in each box for every 100,000 cubic feet of gas to be purified per twenty-four hours. As it is not stated what purifying material is to be used in the boxes, it is to be presumed that the rule is intended to apply to both lime and oxide of iron.

Since the quantity of sulphuretted hydrogen and other sulphur compounds in the gas determines the amount of work to be done in the purifiers, and the English gas coals contain more sulphur, on an average, than the American coals, the English rule may very possibly give an area that is larger than it is necessary to have in this country. For although the work done by a bushel of lime, or a bushel of oxide of iron, per change (which in the case of lime is the whole amount of work obtained) increases with an increase in the ratio between the area of the boxes and the amount of gas to be purified per day, and the cost of labor per 1,000 cubic feet (and in the case of lime of material also) is thus reduced, the increase in size carries with it an increase in the fixed charges for interest and depreciation on the cost of the purifiers and of the house in which they are enclosed, which must sooner or later balance the reduction in operating expenses. The most economical area is therefore that which gives the smallest total for the costs for labor and material and the fixed charges.

The Trustees are not aware of anything having been published in which the question of the balancing of these two items of cost against each other is treated with regard to purification by lime, so for lime purifiers there are no data from which to determine whether the rule given by Newbigging is correct for American conditions. The cost of labor and material being larger with lime than with oxide, lime purifiers must be made larger than oxide purifiers to obtain the most economical results, but with the present knowledge it cannot be said exactly how much larger they should be.

For purification with oxide of iron, the subject of the most economical size of purifiers for use with carburetted water-gas has been investigated by Mr. J. A. P. Crisfield, and the results obtained are given in a paper read by him in October, 1893, before the American Gas Light Association, and published in the Proceedings of the Association, Vol. X, page 217, and in the American Gas Light Journal, Vol. L, page 653, and Progressive Age, Vol. XI, page 356. By means of experiments conducted on a working scale, Mr. Crisfield determined the amounts of gas purified, during one exposure, per cubic foot of oxide for different lengths of time taken by the gas to pass through the oxide contained in three boxes of a four-box set, and also the cost of the labor required to remove the oxide from and replace it in the boxes. From these data the cost of purifying labor per 1,000 cubic feet could be calculated for each length of time that the gas remained in contact with the oxide. The cost of material was not considered, but since with oxide this cost is very small, and is probably not very much affected by the amount of work done per change, it is not important. By combining with the costs of labor the costs of interest and depreciation on the estimated values of the various sized purifiers and purifying houses that would be required to cause gas passing at an assumed rate per hour to stay in contact with the oxide the different lengths of time for which the cost of labor had been obtained, the conclusion was reached that the most economical length of the time of contact was forty-eight seconds. However, in order to provide for the use of oxide of iron less efficient than that used in his experiments, Mr. Crisfield gave the following rule for determining the most economical size of purifying boxes for use with oxide of iron, this rule being based upon a time of contact of sixty seconds. "$60 = \frac{3600V}{3R}$ where V is the volume of oxide" (in cubic feet) "between inlet of first box and point of testing gas and R is the rate" (of make) "per hour. By substitution of the desired rate per hour V becomes known: divide V by 2 or 3, dependent upon whether it is the intention to test on second or third box, and the result is the volume of oxide in one box which may be put into any length, breadth and depth that is convenient.

"The equation may be simplified for convenience to read $R = 20\ V$. Or the volume of oxide between the inlet to the purifiers and the point of testing for sulphuretted hydrogen should be 1/20 of the rate per hour."

Mr. Crisfield apparently intended that the average rate of make throughout the year should be used in this formula, since it is in this way that it has been used to determine the sizes of the boxes necessary. But if this is done, when the make is at the maximum the time of contact falls below the number of seconds stated by him as the limit below which the oxide ceases to do any work. It would seem therefore as if the maximum rate of make should be used instead of the average. Assuming the boxes to be worked three on and one off, as is customary, and the oxide to be in a layer 30 in. deep in each box, as can easily be accomplished in boxes 4 ft. deep, even when a catch layer of shavings is used below the layer of oxide, the rule gives the area required in each box as 42 square feet per 100,000 cubic feet of the maximum twenty-four hours make. If the valve arrangement is such as to permit of all four boxes being worked at once, so that the gas can be tested at the outlet of the third box, the area given by this rule is only 28 square feet per 100,000 cubic feet of the maximum twenty-four hours make.

Mr. Crisfield's experiments having been made with carburetted water-gas, which contains less sulphuretted hydrogen than does coal gas, the area determined by his rule is too small for coal gas work. A common practice is to make the boxes for coal gas work $33\frac{1}{3}\%$ larger than those for carburetted water gas work, an area (in square feet) equal to the maximum make (in 1,000 cu. ft. per 24 hours) multiplied by 0.3 being taken for the latter, while the area of the former is reached by the use of the factor 0.4.

In designing a new set of purifiers it is necessary to make a proper allowance for the probable increase in the amount of gas made, and to take as the maximum make to be provided for, not the make at the time, but such an one as circumstances indicate will be reached within a reasonable time. Proper allowance must also be made when it is known that the gas making materials that are to be used contain an unusually large percentage of sulphur.

145. How would you calculate the strain that the straps used to hold down the cover of a purifying box will be called upon to resist? Illustrate your answer by working out an example.

Ans. The total strain which the holding-down straps on a purifying box cover are called upon to resist is equal to the difference between the lifting force exerted on the cover by the pressure of the gas beneath it and the weight of the cover. The lifting force exerted by the gas, measured in pounds, will be equal to the pressure in pounds per unit of area multiplied by the area upon which the pressure acts. In the case of purifying boxes with water seals, the maximum pressure, in inches of water, that can be exerted on the cover is equal to the depth of the seal, and this pressure should be used in calculating the lifting force of the gas. In the case of purifying boxes with covers bolted on, the maximum pressure to which the cover can be subjected will be determined by the depth of the seal on the syphons through which the condensation is taken away from the boxes, or the pipes connecting them. To convert pressure in inches of water into pressure in pounds per square foot it is necessary to multiply the former by 5.208, the weight in pounds of a volume of water with an area of one square foot and a depth of one inch.

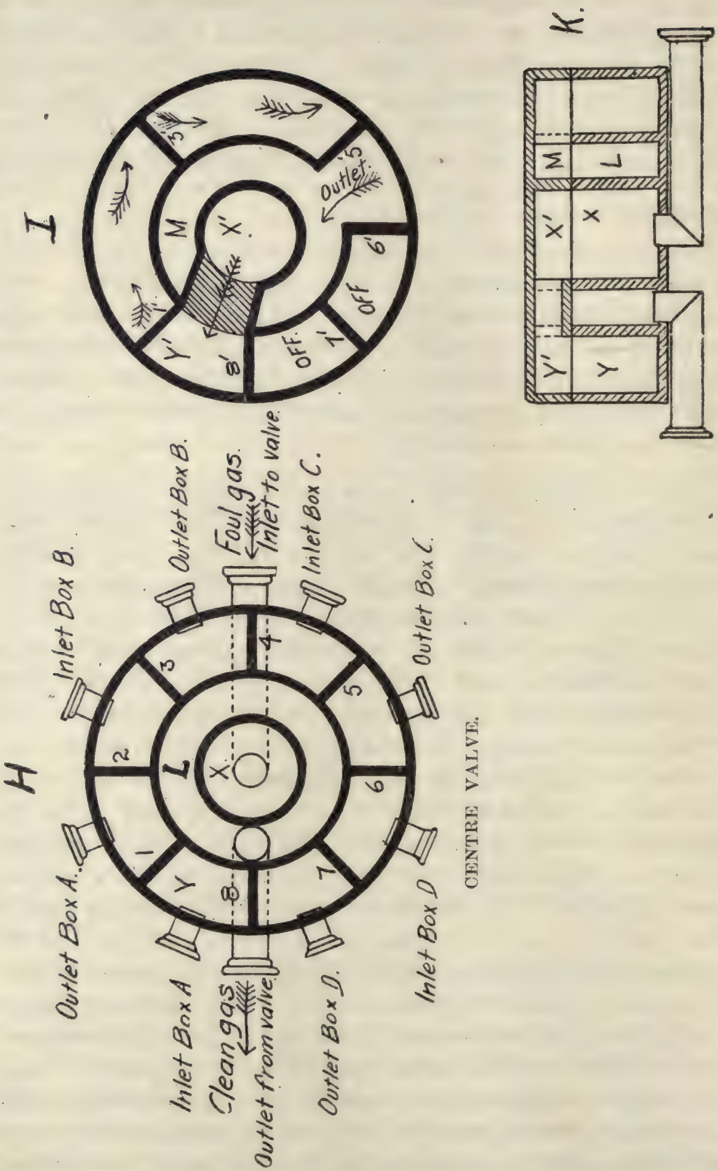
The strain upon any one strap will depend upon the total strain, the design of the cover and the number of straps. When the cover is flat or when it slopes up equally from all four sides, and the straps are spaced equal distances apart, each strap will bear the same strain, which will be equal to the total strain divided by the number of straps. When, however, as is sometimes the case, the cover is arched in one direction only, practically all the strain is borne by the straps on the two sides from which the rise occurs, very little being transmitted to the ends, and to obtain the strain on each strap the total strain should be divided by the number of straps on these sides only.

As an example of the method of working, the case of a cover for a purifying box 10 ft. square and with a cup 24 in. deep, may be taken. The cover may be assumed as weighing 1,500 lb., as being of such design as to throw the strain on all sides equally and as being held down by eight straps, two on each side. As purifying boxes are designated by the size inside, and the cover fits midway in the cup, which is usually about 6 in. wide, the top of the cover will be 10 ft. 6 in.

square and the area on which the gas pressure will act will be 110.25 square feet. As the cover is sealed in water to a depth of 24 in., the pressure under it can never rise above that amount, and the maximum total strain on the straps will therefore be $(110.25 \times 24 \times 5.208) - 1,500 = (110.25 \times 125) - 1,500 = 12,281$ lb. As there are eight straps the strain on each one will be $\frac{12,281}{8} = 1,535$ lb.

146. Give a description, illustrated with sketches, of an ordinary dry centre valve for four purifying boxes built to put three in action at one time, showing the divisions of the seat and cover and describing the action of the valve. Describe also one of the forms of dry centre valve which allow of the use of all four boxes at once.

Ans. The centre valve is a device whereby a set of four purifying boxes may be so operated that one box is thrown out of use for cleaning, the other three being in use, and the gas passing through them in sequence. The position of the cover on the body of the valve determines which box is out of use. The cut shows the construction of the valve, H being the body of the valve, I the cover, and K a vertical section through the cover and the body, showing the cover in place. The body of the valve has a solid bottom, and when the cover is removed is open at the top. The cover, which revolves on the body of the valve, has a solid top, but is open at the bottom, except for that part shown in shaded lines on the section I. The cut shows the cover as it would appear if the top plate were removed. If the cover I were placed over the body of the valve H, each in the positions as shown on the cut, the space marked in the cover Y^1 would exactly correspond with the space Y in the body of the valve. The course of the gas would then be as follows: Entering the inlet to the valve, it would come into the centre space X in the body of the valve. Having no other outlet it would rise into X^1 of the cover. Its only outlet thence would be to Y^1 of the cover, thence to Y of the body of the valve, and thence through the inlet into box A. Passing through box A to its outlet, it would find its only pos-



CENTRE VALVE.

sibility of escape to be into the space 1 of the body of the valve. The partition between Y^1 and 1^1 of the cover of the valve would be over the partition between Y and 1 of the body of the valve. The gas would, therefore, be compelled to rise from 1 of the body of the valve into space 1^1 of the cover of the valve. It could then, in the cover of the valve, pass over the partition between the spaces 1 and 2 in the body of the valve, and down into the space 2 of the body of the valve, which is connected with the inlet of box B. The partition between 1^1 and 3^1 of the cover would be over the partition between spaces 2 and 3 of the body of the valve. The gas then returning from box B, through its outlet into space 3 of the body of the valve, would find its only direction of further progress to be up into the cover of the valve into space 3_1, over the partition between spaces 3 and 4 of the body of the valve, and down into space 4 of the body of the valve, which is connected to the inlet of box C. Passing through box C and out of its outlet into space 5 of the body of the valve, it finds its only direction of further progress to be up into space 5^1 of the cover of the valve. But space 5^1 of the cover of the valve is shut off, by the position of the cover on the body of the valve, from space 6 of the body of the valve, which is connected with the inlet of box D. Therefore, the gas cannot reach the inlet of box D. But space 5^1 of the cover of the valve is open to space M of the cover of the valve, which in turn is open to space L of the body of the valve (spaces M and L are annular rings surrounding the spaces X^1 and X). The gas then would pass from space M of the cover down into space L of the body of the valve, Space L of the body of the valve is directly connected with the clean gas outlet from the valve, and the gas, therefore, would pass, having no other means of egress, through this outlet.

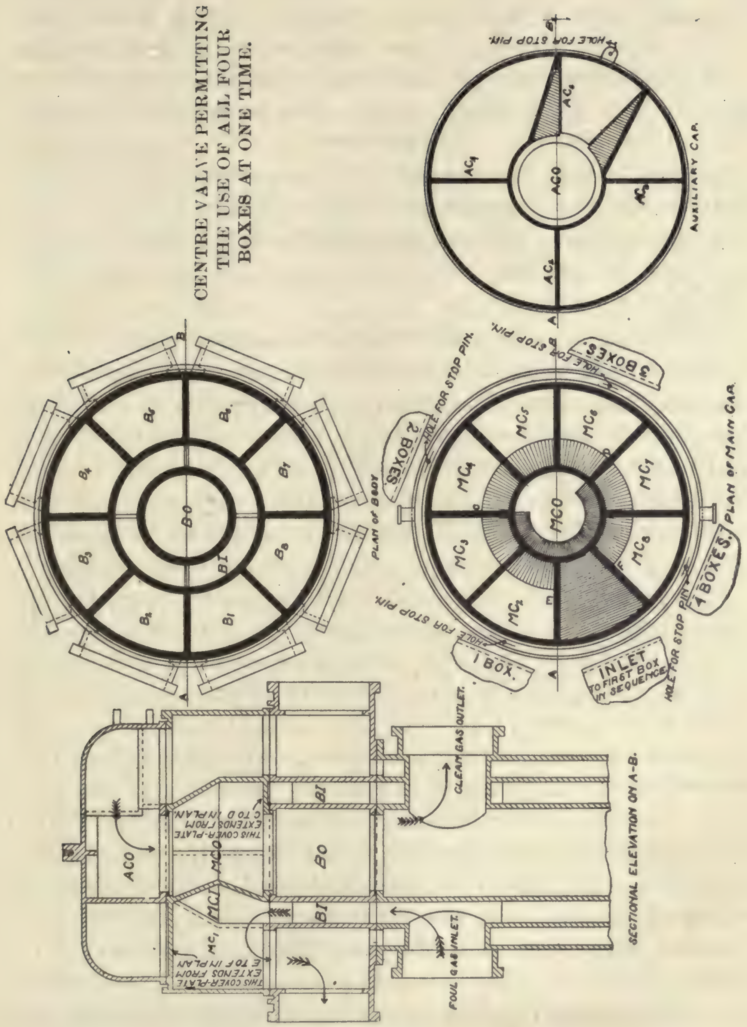
A little study of the cut will show that if the cover were revolved on the body of the valve until space Y^1 of the cover corresponded with space 2 of the body of the valve, which is in connection with the inlet of box B, box B would first receive the gas coming from the valve, and box D would be thrown into the series—box A being shut off. In this position of the valves, spaces 6^1 and 7^1 of the cover would be over spaces Y and 1 of the body of the valve.

If the student will carefully cut out from the diagram of the cover the spaces 1^1, 3^1, 5^1, 6^1, 7^1, Y^1, X^1, and M he will have left the lines showing the walls of the different compartments of the valve, and that part of the bottom of the cover which is solid, namely, the shaded part. If he will then apply this to the cut of the body of the valve, making the circular lines of one correspond with the circular lines of the other, he will be able, by moving the diagram of the cover, to get a better idea of the way in which the valve works, and of the positions which the cover must occupy in order to put one or another of the boxes off for cleaning.

One form of centre valve which is so constructed as to permit of the use of either one, two, three or four purifying boxes at a time is illustrated on the second cut accompanying this answer.

The construction of the body of this valve is the same as that of the corresponding part of the ordinary centre valve, except that the positions of the main inlet and outlet are reversed, the inlet being through the annular portion and the outlet through the central circular portion, but it is provided with two movable covers or caps instead of one. The main cap is free to turn on the body and the upper auxiliary cap turns on the main cap and can be placed and locked in any one of four positions. When it is so locked the two caps can be turned together as if forming only one piece. The position occupied on the main cap by the auxiliary cap determines the number of purifiers that are in use at any one time, while that of the main cap on the body determines which box shall be the first of the series in use independent of the number.

As will be seen by a study of the section and plan shown on the cut, the main cap is entirely open on the bottom except for a plate covering $\frac{3}{8}$ of the annular space corresponding to the annular main inlet in the body. The remaining $\frac{5}{8}$ of this annular space is open at the bottom so that the gas can pass up from the corresponding space in the body, but side walls are arranged, as shown, so that the only outlet from this



CENTRE VALVE PERMITTING THE USE OF ALL FOUR BOXES AT ONE TIME.

space in the cap is through an opening in the outside wall leading into the only one of the eight outer compartments, the same in size and position as the outer compartments in the body, that is covered and not open on top. This being the only compartment open to the inlet it must always serve as the inlet to the first purifier. It will also be seen from the plan that all of the outer compartments of this cap are shut off from the central main outlet, which is open at both top and bottom, and that the gas coming back through the outlet from the first purifier and compartment B_2 of the body into compartment MC_2 of the cap can escape only by passing up into the auxiliary cap.

This auxiliary cap is divided into one central outlet and five outer compartments, all open at the bottom but closed on top. One of the outer compartments, corresponding in shape and area on the bottom with the shape and area of the top of each of the outer compartments in the main cap, is open to the outlet compartment. Three of the other outer compartments, each having bottom openings which cover the top openings of two adjacent compartments of the main cap, are completely isolated from each other and from the central compartment, being open only to the compartments of the main cap over which they lie. The fifth outer compartment never comes into use, being always over either the inlet to a purifier that is off or the covered top of the inlet compartment of the main cap when all four purifiers are in use. This auxiliary cap can be set on the main cap in any one of the four different positions marked by the four lugs shown with holes for the pin that, passing through the hole in the lug on the auxiliary cap into one or the other of them as desired, locks the two caps together so that both can turn on the body in unison. The number of purifiers in use for each position is shown on the plan.

By combining the various sections and plans, it will be seen that when the auxiliary cap is set in the one-box position compartment AC_6 of the auxiliary cap will be directly over compartment MC_2 of the main cap and the gas will travel from the foul gas inlet into and through the annular compartment

BI of the body, compartments MCI and MC_1 of the main cap, and compartment B_1 of the body to the purifier, then from the purifier into and through compartments B_2 of the body, compartment MC_2 of the main cap, compartment AC_6 of the auxiliary cap and the central openings ACO, MCO and BO, in the auxiliary cap, main cap and body respectively, to the main outlet.

If the auxiliary cap is set in the two-box position the travel of the gas is the same until compartment MC_2 of the main cap is reached. As the division wall between compartments AC_6 and AC_4 of the auxiliary cap will be over the division wall between compartments MC_4 and MC_3 of the main cap, the wall between compartments AC_4 and AC_2 will be over that between MC_2 and the covered inlet compartment. Therefore the gas will pass from MC_2 up to AC_4 and going over the wall between MC_2 and MC_3 will pass down through MC_3 into B_3 and thence into the second purifier. Coming back from this it will go through compartments B_4 and MC_4 into AC_6 and from there to the main outlet as before.

By the aid of templates, cut out as advised for the ordinary centre valve, the members of the class can work out the course of the gas when three or four purifiers are put in action, and can also see how turning the two caps together will bring each box in succession first in the series without altering the number in action.

147. Which of the impurities of crude gas are removed by iron sponge or mass, and which by lime?

Ans. Iron sponge, or iron mass, possesses the property of combining with sulphuretted hydrogen, but has no affinity for carbon dioxide. As oxide of iron pure and simple, it has no affinity for bisulphide of carbon or other sulphocarbon compounds, but after having been revivified, the free sulphur present in the mass has the power of arresting a portion of the bisulphide of carbon.

Lime has a strong affinity for carbon dioxide and sulphuretted hydrogen, and entirely removes these compounds from the gas. After having absorbed sulphuretted hydrogen it has also a more or less uncertain affinity for bisulphide of carbon.

148. Name the impurities that are removed from crude illuminating gas by chemical action and the substances employed for their removal, and give as far as possible the chemistry of the operation.

Ans. The impurities that are removed from crude illuminating gas entirely by chemical action are, sulphuretted hydrogen, H_2S, bisulphide of carbon, CS_2, cyanogen, CN, and carbon dioxide, CO_2. Ammonia, NH_3, is removed from coal gas partly by chemical action and partly by simple solution in water, a physical action.

The substances which serve for the removal of ammonia chemically are the carbon dioxide and sulphuretted hydrogen in the gas itself and conversely the ammonia serves for the partial removal of the carbon dioxide and sulphuretted hydrogen. The reactions by which these three impurities combine with each other can, and should, be utilized to the greatest possible extent by washing or scrubbing the gas with the ammoniacal liquor deposited in the hydraulic main and the condensers. In this way the purifiers can be relieved of much work that would otherwise be thrown upon them. The carbonate and sulphide of ammonium formed do not contain definite proportions of the different substances, so no exact chemical reactions can be given.

The excess of sulphuretted hydrogen that cannot be removed by the ammonia may be taken out either by hydrated sesqui-oxide of iron, or ferric oxide, the active material in iron sponge, or mass, or by hydrate of lime, slaked lime. In England a substance called Weldon Mud, a by-product from the manufacture of bleaching powder, the active ingredient in which is manganese dioxide, is also used in the purifiers for the removal of sulphuretted hydrogen, but none of it is employed in this country. Ferric oxide is, as a rule, cheaper than lime for the purpose. Its composition when freshly made is expressed by the formula $Fe_2O_3.3H_2O$, which means that a molecule is composed of two atoms of iron, three atoms of oxygen and three molecules of water, but under the conditions to which it is exposed in practice it loses water, and its actual composition as employed in gas works is probably that expressed by the formula $Fe_2O_3.H_2O$. The reactions occurring in the purifiers between ferric oxide and sulphuretted hydrogen are expressed by the equations

$$Fe_2O_3.\ H_2O + 3H_2S = Fe_2S_3 + 4H_2O \text{ and}$$
$$Fe_2O_3.\ H_2O + 3H_2S = 2\ FeS + S + 4H_2O$$

of which the first is the principal one, only 17 per cent. to 30 per cent. of the sulphuretted hydrogen being taken up according to the second.

Ferric oxide will also absorb cyanogen to a certain extent, but if it is desirable to remove this substance in marketable form, it is better to absorb it by scrubbing the gas, before the ammonia and sulphuretted hydrogen are taken out of it, with a concentrated solution of sulphate of iron, $Fe\,SO_4$. The ammonia and sulphuretted hydrogen act on this solution to form sulphide of iron, FeS, and sulphate of ammonia, $(NH_4)_2SO_4$, according to the equation $FeSO_4 + H_2S + 2NH_3 = FeS + (NH_4)_2\,SO_4$, and then the sulphide of iron acts on the cyanogen and the ammonia to form an insoluble double salt of ferrocyanide and ammonium, thus $2FeS + 6NH_4CN = (NH_4)_2Fe_2(CN)_6 + 2(NH_4)_2S$. This compound of ferrocyanide and ammonium flows from the scrubber as a liquid mud and the cyanogen is obtained by treating it in the proper manner. (American Gas Light Journal, Vol. LXXIII, page 564.)

Hydrate of lime, $CaO.\ H_2O$ or $Ca(HO)_2$, slaked lime, is sometimes employed for the removal of sulphuretted hydrogen, but is, in most cases, more expensive than ferric oxide, and its use should be, as a rule, confined to the removal of carbon dioxide when it is considered advisable to remove this impurity. The reaction between lime and carbon dioxide is expressed by the equation $Ca(HO)_2 + CO_2 = CaCO_3 + H_2O$.

The substance employed for the removal from gas of bisulphide of carbon, CS_2, when a special effort is made to remove this impurity, is the sulphided lime obtained by passing through slaked lime gas containing sulphuretted hydrogen, but no carbon dioxide nor oxygen. The exact composition of the compound of lime and sulphur formed by thus fouling slaked lime is not known, but it is supposed to be either calcium hydrosulphide, $Ca(SH)_2$, or calcium hydroxyhydrosulphide, $CaOH.SH$. In practice the slaked lime is sulphided after it has been placed in the purifying box, by passing through it in the usual way, and preferably while it is still warm, gas freed from carbon dioxide and oxygen, but containing sulphuretted hydrogen. When the lime is sulphided the valves are so set that the gas enters the box after having been freed from carbon dioxide and sulphuretted hydrogen. In this country it is not usual to make any special effort to remove bisulphide of carbon from illuminating gas, since carburetted water gas and the coal gas made from the majority of the gas coals do not contain any excessive amount of this impurity, and both lime used in the ordinary way and the free sulphur contained in oxide of iron that has been fouled and revivified several times will absorb enough of it to bring the amount left in the gas below the point where its presence would be noticed when the gas is burned.

149. Explain the chemistry of that part of the process of purification which is carried on in the purifying boxes, including the removal of carbon dioxide and sulphuretted hydrogen by lime and the removal of sulphuretted hydrogen by oxide of iron. Give as far as you can the reactions occurring in each instance.

Ans. When gas containing carbon dioxide, CO_2, and sulphuretted hydrogen, H_2S, comes into contact with slaked lime or calcic hydrate, $Ca(HO)_2$, both of these substances combine with the lime, forming carbonate and sulphide of lime, $CaCO_3$ and CaS, respectively. This double absorption continues until nearly all of the lime has been acted upon. If after this point has been reached the mixture of carbonate and sulphide of lime is still exposed to the gas, the sulphide will be changed to carbonate by the substitution of carbon dioxide for the sulphur, on account of the affinity between lime and carbon dioxide being stronger than that between lime and sulphur, and as a result of this substitution, sulphuretted hydrogen will be set free to pass forward with the gas. If the lime is used to remove carbon dioxide only, this substitution is allowed to go on until the sulphur has been entirely driven out of the lime, the sulphuretted hydrogen being absorbed by means of oxide of iron in additional purifiers; but if the lime is used for the removal of both carbon dioxide and sulphuretted hydrogen, the first box must be taken off for cleaning and refilling as soon as sulphuretted hydrogen shows at the outlet of the next to the last box in action, at which time there will still be considerable sulphide of lime left in the first box. It is not necessary to test for carbon dioxide in this case, since none can be present as long as the gas is free from sulphuretted hydrogen.

The reactions occurring between the lime and the impurities and between the carbon dioxide and sulphide of lime are expressed by these equations:

$$Ca(HO)_2 + H_2S = CaS + 2H_2O$$
$$Ca(HO)_2 + CO_2 = CaCO_3 + H_2O$$
$$CaS + CO_2 + H_2O = CaCO_3 + H_2S.$$

When oxide of iron is used for the removal of sulphuretted hydrogen, either alone or in connection with lime used for removing carbon dioxide, as the sulphuretted hydrogen comes in contact with the hydrated ferric oxide or sesquioxide of iron, $Fe_2 O_3.H_2O$, in the purifiers, the sulphur of the former unites with the iron and forms iron sulphide, and the hydrogen unites with the oxygen and forms water. At the same time part of the sulphur of the sulphuretted hydrogen is liberated in a free state.

The probable chemical changes are shown by the equations:

$$Fe_2O_3.H_2O + 3H_2S = Fe_2S_3 + 4H_2O \text{ and}$$
$$Fe_2O_3.H_2O + 3H_2S = 2FeS + S + 4H_2O.$$

It is supposed that from 17% to 30% of the sulphuretted hydrogen absorbed by the oxide is absorbed according to the second equation, and the rest according to the first equation.

150. What change occurs in foul "iron oxide" when it is exposed to the atmosphere, after use in the boxes? Give a general answer, and then give the chemistry of the operation as far as you can.

Ans. After "iron oxide" has been fouled it is exposed to the air. The iron of the iron sulphide unites with the oxygen of the air, and with the water that is present in the shape of moisture in the mass and in the atmosphere and again forms ferric oxide, the sulphur being liberated in the free state.

Omitting the moisture, the probable chemical changes are shown by these equations:

$$2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 3S_2$$
$$12FeS + 9O_2 = 6Fe_2O_3 + 6S_2$$

151. What is the influence of heat upon the chemical reactions that occur in the purifiers, and what bearing does this influence have upon the question of the heating of purifying houses, revivifying sheds and lime rooms?

Ans. The chemical reactions occurring in the purifiers between lime or ferric oxide and the sulphuretted hydrogen (and in the case of lime the carbon dioxide also) in the gas, are rendered more rapid and complete by heat. It has been found that at temperatures below 32° F. both lime and ferric oxide are practically inactive with reference to sulphuretted hydrogen, and that as the temperature increases, more and more of the impurities are absorbed until at temperatures of 100° F. to 120° F. the action becomes as complete as it can be made under working conditions. It follows from this, that to secure good results in purification, purifying houses, lime rooms and revivifying sheds should always be maintained at a temperature not lower than 60° F., and further advantage may be derived from heating the gas itself as it enters the purifiers to a temperature of from 100° F. to 120° F.

152. What are the respective arguments in favor of the use of lime and of oxide of iron for the purification of illuminating gas?

Ans. It is argued in favor of the use of lime for purification, either alone or in combination with iron oxide, that as it removes from the gas a larger portion of the sulphur compounds than is taken out by oxide and all the carbon dioxide, for which the oxide has no affinity, the resulting gas is purer and of higher illuminating value than the same gas would be if purified by oxide alone, and will, moreover, burn with a whiter and more brilliant flame than can be obtained from a gas containing carbon dioxide even though the loss of illuminating power due to the presence of the carbon dioxide is made up by the use of a larger quantity of enricher. These advantages it is claimed are fully worth the extra cost of lime purification over that of oxide purification even when lime is comparatively expensive.

The advocates of the use of oxide of iron alone contend on the the other hand that most of the gas coal used in America yields a gas containing such a small quantity of sulphur compounds, other than sulphuretted hydrogen, that there is no necessity for the removal of any portion of them, and that as usually employed in this country lime is no more effective than oxide in removing such compounds from gas. (Water gas contains even smaller amounts of these sulphur compounds than coal gas.) In contradiction to the statement that owing to the detrimental effect of the carbon dioxide, gas purified with oxide will have a lower illuminating value than the same gas would have had if purified with lime, it is claimed that careful comparisons of manufacturing results have shown that the change from lime purification to oxide purification does not cause any reduction in the illuminating value of the gas, other things being equal, owing to the fact that, as shown by analysis, the gas purified by oxide will contain a larger percentage of heavy hydrocarbons than similar gas purified by lime, and this extra amount of illuminants counterbalances the detrimental effect of the carbon dioxide.

It is also claimed that there is no noticeable difference between the flame produced by burning a gas containing the comparatively small percentage of carbon dioxide that would be found in a well made gas purified by iron oxide and that produced by a gas entirely free from carbon dioxide, the rate of combustion and the illuminating value of the gas being the same in both cases, and that, even if the illuminating value of gas purified by oxide, should be slightly less than it would be if the carbon dioxide were removed by lime purification, the difference is so small that in most cases the cost of extra enrichment is much less than the extra cost of lime purification.

In other words, the advocates of purification by iron oxide alone claim that there is practically no difference between the gas purified by lime and that purified by oxide, except that possibly the latter may show a slight loss in illuminating value, which can be made up at a cost much smaller than that of lime purification.

The use of a coal containing a large percentage of sulphur, and the existence of very stringent regulations as to the amount of sulphur allowed in the gas, may make the use of lime necessary for the removal of the sulphur compounds from the gas.

153. How would you prepare lime for use in purifying gas?

Ans. Schilling, in the 1858 edition, page 75, gives the following directions:

"The degree of moisture is of the greatest importance. In many works the rule is to slake the lime in such a manner that it will neither fall into powder nor adhere to the fingers when compressed. * * * * * In this condition, however, the lime is too dry; it causes much pressure. It is hardly possible to indicate precisely the quantity of water required for a given weight of lime, but there will be little danger of error in operating as follows: Spread the quicklime over a stone floor, and surround it with a slight dyke of slaked lime, to prevent the water from running off; then slake it with water thrown upon the mass. It is then to be well mixed and turned over, until the whole forms a thick and homogeneous mass. It must then be thrown up in a heap, and left undisturbed until the next day, when it must be again worked over and the lumps broken."

Theobald Forstall later improved upon the Schilling method, and in a paper read before the American Gas Light Association, described his improvement in the following language:

"A simple and effective means of gauging the proper degree of moisture, and securing its uniformity throughout the whole charge of lime operated upon, is to pass the slaked lime through a wire screen, with an open mesh of one square inch area, placed at an angle of 70° with the floor. This screening reduces the lumps into granular pellets of irregular form and size, the largest of which do not exceed the bulk of a small hickory nut. The proper degree of moisture is that beyond which any excess would cause the 'dough' to adhere to the screen instead of breaking through. Slight variations of moisture, in different portions of the charge, are corrected by the thorough mingling of the whole in the screening. The pellets do not adhere to one another spontaneously; they can be shoveled into barrows and reshoveled into purifiers, without losing their independence; but the slightest compression and working in the hand will resolve them immediately into adhesive putty."

The Trustees recommend to the students that they read Mr. Forstall's paper, which may be found in the Proceedings of the American Gas Light Association for 1875; in the Journal of Gas Lighting, Vol. XXVI, page 364; or in King's Treatise, Vol. 1, page 425.

154. Describe some method of making iron oxide, to be used for the removal of sulphuretted hydrogen from gas during its purification.

Ans. The iron oxide, or sponge as it is sometimes called, which is used for removing sulphuretted hydrogen from gas, is prepared by thoroughly oxidizing or rusting iron in the shape of borings and mixing it with planer chips so as to make the material more permeable by the gas. To produce a good material, the iron must be present in sufficient quantity, must be thoroughly oxidized into the hydrated sesquioxide and must be uniformly distributed throughout the planer chips.

The iron should be in the shape of cast iron borings free from oil, the finer the better, and should be used in the proportion of from 20 lb. to 25 lb. to each bushel of planer chips. The chips should be clean and free from dust. To prepare the material, the desired number of bushels of planer chips are measured out and spread to a depth of about 18 in. on a floor preferably paved with brick or cement, and are then sprinkled with water, turned, again sprinkled and turned, and so on until the whole mass is uniformly wet, but not soggy. This wetting of the chips is for the purpose of causing the particles of iron to adhere to them. An amount of iron borings equal to 5 lb. per bushel of chips used is then weighed out, spread evenly over the top of the wet chips and mixed with them by turning the mass and wetting it while it is being turned. This operation is repeated until the whole amount of iron to be used has been added and is mixed evenly throughout the mass, which on the last turning is brought up to a depth of 24 in.

The iron by this time should have begun to oxidize rapidly, and the heat produced by this oxidation will cause the mass to grow quite hot. To prevent the temperature from becoming excessive, as well as to expose fresh surfaces of the iron to the oxidizing influence of the water and the air, the mass must be turned and wet at comparatively short intervals. It may at first have to be turned every ten or twelve hours, but as the oxidation of the iron becomes more complete, the heating will not be as rapid and the intervals can be made longer. In any case these intervals must be sufficiently short to keep the mass damp and prevent any dehydration of the oxide by overheating and drying. The wetting and turning must be continued until all the iron is thoroughly oxidized, the attainment of this condition being shown by the cooling down of the mass, by the changing of the color to a reddish brown, and by the absence of any particles of unoxidized iron as determined by a close inspection of the mass. During the several turnings care must be taken to break up all the lumps found, since the iron in the interior of such lumps cannot be acted upon by the air and the water. When the oxidation is complete, the chips should all be covered with oxide and should not adhere to each other.

Brine and ammoniacal liquor are sometimes used for wetting the chips and the iron instead of water, the oxidation of the iron being hastened by their use. Sawdust is also sometimes used in place of planer chips, the argument in its favor being that there is less loss of oxide by its blowing away as dust during the handling of the material when in use than occurs when the chips are employed. The oxide made with chips does not, however, pack as tightly in the purifiers as does that made with sawdust, and therefore does not throw as much pressure, and the majority of engineers prefer oxide made with chips to that made with sawdust.

155. From the reactions between slaked lime, $Ca(HO)_2$ or $CaO.H_2O$, and carbon dioxide, CO_2, and between ferric oxide, $Fe_2O_3.H_2O$, and sulphuretted hydrogen, H_2S, as given in the answer to question No. 149, calculate the weight of carbon dioxide that can theoretically be absorbed by one pound of lime and the weight of sulphuretted hydrogen that can theoretically be absorbed by one pound of ferric oxide. Give your calculations.

Ans. The equation according to which slaked lime combines with carbon dioxide is as follows:

$$Ca(HO)_2 + CO_2 = CaCO_3 + H_2O$$

The molecular weight of $Ca(HO)_2$ is 74; the molecular weight of CO_2 is 44. Therefore, 74 parts by weight of $Ca(HO)_2$ combine with 44 parts by weight of CO_2.

Then 1 lb. of slaked lime will combine with 0.5946 lb. of carbon dioxide according to the proportion

$$74 : 44 :: 1 : x = 0.5946$$

The equations according to which $Fe_2O_3.H_2O$ combines with H_2S are as follows:

$$Fe_2O_3.H_2O + 3H_2S = Fe_2S_3 + 4H_2O$$
$$Fe_2O_3.H_2O + 3H_2S = 2FeS + 4H_2O + S$$

The molecular weight of $Fe_2O_3.H_2O$ is 178; 3 times the molecular weight of H_2S is 102.

Then in a manner analogous to that above we have,

$$178 : 102 :: 1 : x = 0.573 \text{ lb.}$$

156. What is the maximum amount of gas containing 320 grains of sulphuretted hydrogen, H_2S, per 100 cubic feet that can theoretically be purified by a bushel of purifying material containing thirty pounds of hydrated sesqui-oxide of iron, $Fe_2O_3.H_2O$? It is assumed that no oxygen is present in the gas.

Ans. The answer to question No. 155 shows that each pound of sesqui-oxide of iron, $Fe_2O_3.H_2O$, will combine with 0.573 lb. of sulphuretted hydrogen, H_2S. Therefore, the thirty pounds of oxide contained in a bushel of the purifying material specified can theoretically absorb $30 \times 0.573 = 17.19$ lb. of sulphuretted hydrogen. Since the gas contains 320 grains of sulphuretted hydrogen per 100 cubic feet, it will contain 3,200 grains, or 0.46 lb. (one pound equals 7,000 grains) per 1,000 cubic feet. $17.19 \div 0.46 = 37.37$, hence a bushel of purifying material containing thirty pounds of hydrated sesqui-oxide of iron will theoretically purify, during one exposure, 37,370 cubic feet of gas which contains 320 grains of sulphuretted hydrogen per 100 cubic feet.

Obviously, the amount of gas that can be purified will vary according to the quantity of H_2S in the gas, and also according to the weight of $Fe_2O_3.H_2O$ contained in a bushel of material.

It is also possible by admitting oxygen with the gas and thus securing a continuous partial revivification, to purify more gas to an exposure than is indicated by the method of calculation given above. Unless oxygen is supplied, however, the duty actually obtained in practice from any material will always be less than the theoretical amount obtained by calculation, as it is impossible, under working conditions, to thoroughly saturate with H_2S all the $Fe_2O_3.H_2O$ in the material.

157. What is the maximum amount of gas containing 0.85% by volume of H_2S that can be theoretically purified at one exposure by a bushel of iron sponge, or mass, which contains an amount of $Fe_2O_3.H_2O$, equivalent to a weight of 25 lb. of iron? It is assumed that no oxygen is present in the gas. (Give the reaction, or reactions, upon which you base your figures, and also give your calculations.)

Ans. The atomic weights of the various elements which enter into combination to form ferric hydrate, $Fe_2O_3.H_2O$, being iron, Fe, 56, oxygen, O, 16 and hydrogen, H, 1, a molecule of $Fe_2O_3.H_2O$ will contain $56 \times 2 + 16 \times 3 + 1 \times 2 + 16 = 178$ parts by weight of which 112 parts are iron, and therefore 25 lb. of iron will form $25 \times \frac{178}{112} = 39.7$ lb. of ferric hydrate.

According to W. J. Atkinson Butterfield the reactions on which the removal of sulphuretted hydrogen, H_2S, from gas by $Fe_2O_3.H_2O$ chiefly depend are as follows:

$$Fe_2O_3.H_2O + 3\ H_2S = Fe_2S_3 + 4\ H_2O$$

$$Fe_2O_3.H_2O + 3\ H_2S = 2\ FeS + S + 4\ H_2O$$

The proportion between $Fe_2O_3.H_2O$ and H_2S being the same in both these equations, the amount of H_2S absorbed by a given quantity of $Fe_2O_3.H_2O$ will be the same no matter what combination of the two reactions actually occurs.

The atomic weight of sulphur, S, is 32, so the weight of sulphuretted hydrogen, H_2S, entering into the reaction is $3(2 \times 1 + 32) = 3 \times 34 = 102$. Therefore 178 parts by weight of $Fe_2O_3.H_2O$ will combine with 102 parts of H_2S, or one pound will combine with $\frac{102}{178} = 0.573$ lb., and 39.7 lb. of $Fe_2O_3.H_2O$ will combine with $39.7 \times 0.573 = 22.748$ lb. of H_2S. But one pound of dry H_2S at 60° F. and 30 in. barometer occupies a volume of 11.1229 cubic feet, so 22.748 lb. will correspond to $22.748 \times 11.1229 = 253.02$ cubic feet of H_2S.

As the gas is assumed to contain 0.85% by volume of H_2S it will contain 8.5 cubic feet of H_2S per 1,000 cubic feet. $\frac{253.02}{8.5} = 29.767$, and therefore 29,767 cubic feet is the maximum amount of gas containing 0.85% of H_2S that can theoretically be purified during one exposure by a bushel of purifying material which contains an amount of $Fe_2O_3.H_2O$, equivalent to a weight of 25 lb. of iron. Obviously the amount will vary according to the quantity of H_2S in the gas, and also according to the weight of $Fe_2O_3.H_2O$ contained in a bushel of material.

It is also possible by admitting oxygen with the gas, and thus securing a continuous partial revivification, to purify more gas to an exposure than is indicated by the method of calculation given above. Unless oxygen is supplied, however, the duty actually obtained in practice from any material will always be less than the theoretical amount obtained by calculation, as it is impossible, under working conditions, to thoroughly saturate with H_2S all the $Fe_2O_3.H_2O$ in the material.

158. What is the maximum amount of gas containing 2.25% of carbon dioxide, CO_2, that can theoretically be purified by a

bushel of unslaked lime containing 86% calcic oxide, CaO, assuming that the weight of a bushel is 80 lb. and that carbon dioxide only is to be removed from the gas by the lime? Give all your calculations.

Ans. As the bushel of lime weighs 80 lb. and contains 86% of CaO it will contain 68.8 lb. of CaO. When the lime is slaked, hydrate is formed according to the reaction.

$$\underset{\text{Lime}}{CaO} + \underset{\text{Water}}{H_2O} = \underset{\text{Calcic hydrate}}{Ca(HO)_2}$$

Since the atomic weight of calcium, Ca, is 40, that of oxygen, O, 16 and that of hydrogen, H, 1, the respective weights are $(40 + 16) + (2 + 16) = [40 + (17 \times 2)]$, or $56 + 18 = 74$. That is, 56 lb. of CaO will make 74 lb. of $Ca(HO)_2$ and 68.8 lb. of CaO will make $68.8 \times \frac{74}{56} = 68.8 \times 1.321 = 90.88$ lb. of $Ca(HO)_2$.

The equation of the reaction between $Ca(HO)_2$ and CO_2 is: $Ca(HO)_2 + CO_2 = CaCO_3 + H_2O$, the weights being $[40 + (17 \times 2)] + [12 + (16 \times 2)] = [40 + 12 + (16 \times 3)] + [(1 \times 2) + 16]$ or $74 + 44 = 100 + 18$.

We are only concerned with the first half of the equation, from which we see that 74 lb. of $Ca(HO)_2$ will combine with 44 lb. of CO_2. Therefore 90.88 lb. of $Ca(HO)_2$ will combine with $90.88 \times \frac{44}{74} = 54.04$ lb. of CO_2. CO_2 dry at 60° Fahrenheit and 30 in. barometer weighs 1 lb. for each 8.595 cubic feet, so 54.04 lb. will be $54.04 \times 8.595 = 464.47$ cubic feet. The gas in question contains 2.25% of CO_2, or 22.5 cubic feet per 1,000 cubic feet. $\frac{464.47}{22.5} = 20,643$ and 20,643 cubic feet is the maximum amount of gas containing 2.25% of CO_2 that can be purified by a bushel of unslaked lime weighing 80 lb. and containing 86% of CaO. Of course, this result could not be reached in practice, as it is never possible to entirely saturate all the calcic hydrate with carbon dioxide under working conditions, even assuming that all the other impurities that would combine with $Ca(HO)_2$ are removed by other means.

159. What is the maximum amount of gas containing 1.6% by volume of carbon dioxide, CO_2, and 0.90% by volume of sulphuretted hydrogen, H_2S, that can theoretically be purified by a bushel of unslaked lime containing 87% of calcic oxide, CaO, assuming that the weight of a bushel is 80 lb. and that both the carbon dioxide and the sulphuretted hydrogen are to be removed by the lime? Give all your calculations.

Ans. As the bushel of lime weighs 80 lb. and contains 87% of calcic oxide, CaO, it will contain 69.6 lb. of calcic oxide. When the lime is slaked 69.6 lb. of calcic oxide will produce (see answer to question No. 158) 69.6 × 1.321 = 91.94 lb. of calcic hydrate.

When lime is used to remove both carbon dioxide, CO_2, and sulphuretted hydrogen, H_2S, from gas, it will, until nearly saturated, combine with each of these impurities just as if the other were not present, and it does not introduce any great error into the calculation to assume that this continues to be the case until the lime is entirely saturated.

Since the gas contains 1.6% of carbon dioxide and 0.9% of sulphuretted hydrogen, there are in every 1,000 cubic feet of the gas 16 cubic feet of carbon dioxide and 9 cubic feet of sulphuretted hydrogen. A cubic foot of carbon dioxide weighs 0.11634 lb. and 16 cubic feet weigh 0.11634 × 16 = 1.86 lb. A cubic foot of sulphuretted hydrogen weighs 0.0899 lb., so 9 cubic feet weigh 0.0899 × 9 = 0.81 lb. The reactions by which the lime removes the carbon dioxide and sulphuretted hydrogen are, as given in the answer to question No. 149:

(1) $Ca(HO)_2 + CO_2 = CaCO_3 + H_2O$, and
(2) $Ca(HO)_2 + H_2S = CaS + 2H_2O$.

The atomic weights of calcium, oxygen and hydrogen being as given in the answer to question No. 158, and those of carbon and sulphur being 12 and 32 respectively, the proportionate weights are:

(1) $74 + 44 = 100 + 18$, and
(2) $74 + 34 = 72 + 36$,

showing that 74 pounds of calcic hydrate will combine with 44 pounds of carbon dioxide, or 34 pounds of sulphuretted hydrogen. Therefore, one pound of carbon dioxide will neutralize $\frac{74}{44} = 1.681$ lb. of calcic hydrate, and one pound of sulphuretted hydrogen will neutralize $\frac{74}{34} = 2.176$ lb. of calcic hydrate. The amount of carbon dioxide and sulphuretted hydrogen present in 1,000 cubic feet of the gas in question will therefore neutralize $1.86 \times 1.681 + 0.81 \times 2.176 = 3.13 + 1.76 = 4.89$ lb. of calcic hydrate, and the 91.94 lb. produced as above from the bushel of unslaked lime of the given composition will be theoretically capable of purifying $\frac{91.94}{4.89} = 18{,}800$ cubic feet of gas containing 1.6% by volume of carbon dioxide, CO_2, and 0.90% by volume of sulphuretted hydrogen, H_2S.

Of course this result cannot be obtained in practice, as it is impossible to thoroughly saturate the calcic hydrate with the impurities under working conditions, and therefore the actual manufacturing results will always be less than the results that are theoretically possible.

160. Describe the proper treatment of iron oxide from the time it is taken out of the box for revivification until it is again returned to the box.

Ans. As probably no two samples of iron oxide (the words being used to denote a purifying material in which the active agent is hydrated ferric oxide) are exactly alike, it is impossible to lay down hard and fast rules that will apply in all cases. But there is one truth that must always be borne in mind and acted upon to secure the best results. This is, that revivification will be the more rapid and complete, the higher (within reasonable limits) the temperature of the oxide. Therefore, the treatment should be such as to retain, as far as possible, in the material, all the heat generated by the chemical action that occurs, provided, of course, that this heat is not excessive.

At a works using oxide purchased from three different firms, the following method of handling during revivification was found to give the best results :

As the oxide was removed from the box it was thrown on to the revivifying floor, beneath the box, in two heaps, each about 8 feet high, and allowed to remain in these heaps until it was thoroughly heated, the length of time required for the attainment of this result varying from one or two hours for fresh, active oxide, to 48 hours or more for that nearly spent, or sluggish from any other causes. When hot it was taken from the heaps and placed on the floor, in long ridges, whose cross section was approximately an equilateral triangle with 24 inch sides. Spaces were left between the ridges, and as the oxide on the two exposed faces revivified, as shown by its change of color, it was scraped down into these spaces until the whole batch was spread out in a layer, with a uniform depth of about 9 to 10 inches. It was then turned over with shovels, care being taken to have it really *turned* and the material that had been on the bottom placed on top, instead of the whole mass being merely shoveled to one side, which is very often all that the so-called turning over amounts to. By this time it was usually thoroughly revivified. If not it was again turned over as often as necessary. When revivified the batch was piled in a heap about 6 feet high and 4 to 6 feet wide, to remain until it was put back into the box in due course. Sufficient time was allowed to elapse between each handling for complete revivification of the top layer of oxide. During the operation the oxide was never wet, unless it became excessively heated, or so dry that there was a loss and a nuisance in handling, owing to the dust arising from it. By thus keeping the oxide as dry as possible, all the heat produced by chemical action was made available for maintaining the temperature of the material and thus promoting complete revivification, instead of being used up in vaporizing the added water.

In handling batches of fresh oxide care must be taken to prevent their becoming so highly heated as to ignite the sulphur and shavings contained in them. Even in such cases, however, it is better to allow the oxide to stay in heaps, as since less surface is exposed to the air in this way the liability of ignition is less, and if it does occur the fire can be more readily extinguished by the use of water. Such heaps should be examined at frequent intervals and any tendency to fire promptly corrected. Ignition cannot occur with wet oxide until the water has been practically all evaporated, so wetting the oxide will always prevent it. But as wetting also retards revivification it should only be resorted to in cases of necessity. Spreading the oxide out in thin layers and turning it constantly will also cool it.

If the batch of oxide does not heat and revivify properly when handled as above, and its record shows that it is not yet saturated with sulphur, it can sometimes be brought into good condition again by being exposed out-of-doors in the sun during the warm weather, the sun imparting the heat necessary to start and maintain the revivification. Or the batch can be heated artificially.

Another method of revivification consists in placing the oxide, when taken from the heaps, on a platform of purifier trays supported about a foot above the floor of the revivifying room in such a way as to permit a free circulation of air underneath the whole bed, the oxide being spread in a layer 24 in. to 30 in. deep. When using such a platform, revivification takes place on the bottom as well as at the top of the layer, proceeding faster on the bottom. When the batch is turned the oxide still foul should be put on the trays, and the oxide that has revivified either piled to one side or placed on top of the foul oxide. If this method is used with active oxide great care will be necessary to prevent firing, as revivification proceeds very rapidly owing to the fact that air passes up through the oxide instead of merely being in contact with it.

161. Describe an arrangement by which the percentage of air admitted for continuous revivification of the oxide in the purifying boxes can be kept under control.

Ans. An arrangement for delivering a regulated amount of air for the continuous revivification of the oxide of iron in the purifying boxes that is simple and is coming largely into use consists of a small positive blower driven by a belt from a shaft of the exhauster used in pumping the gas from the retorts in the case of a coal gas works and from the relief holder in a carburetted water gas works. The respective capacities per revolution of the exhauster and the blower being known, the relation between the speed of the blower and that of the exhauster for any given percentage of air desired can be readily calculated, and the pulleys required to produce this relation placed upon the two shafts. When it is desired to make a change in the percentage of air being used it can be done by making the proper change in the size of the pulley on the blower shaft. When such an arrangement is first installed the accuracy obtained in the desired relation between the amount of gas passed by the exhauster and that of air furnished by the blower should be checked by passing the air through a meter and comparing the readings of this meter with those of the station meter, and this check by measurement of the air should be repeated at regular intervals so as to be certain that the desired percentage of air is being furnished. It will not be necessary, however, to take continuous measurements of the amount since the arrangement is sufficiently positive to be relied upon for the interval between checks. The air pipe should be provided either with a water seal or a check valve, which will prevent any gas from escaping when the exhauster is stopped for any reason, as when this occurs the blower will stop also, and if neither a seal nor check valve is provided gas will blow back out of the air pipe.

In a coal gas plant where there is a sufficiently high vacuum at the inlet of the exhauster the air required can be drawn by means of this vacuum into the exhauster inlet through a safety seal and a dry meter. When this arrangement is adopted the quantity of air that is being drawn in should be checked at frequent intervals by reading the station meter and the air meter and comparing these readings to see if the amount of air is the proper percentage of that of gas. If the percentage is not correct the necessary adjustment should be made on the stopcock with which the air pipe is provided. This method requires less apparatus than the one first described, but on the other hand it calls for a greater amount of supervision.

162. Give a description of some method of revivifying iron oxide without removing it from the purifying boxes, and state the precautions that should be observed to prevent the oxide from firing during the operation.

Ans. The simplest way of revivifying iron oxide without removing it from the purifying box is to have a pipe connection that can be temporarily attached to the cleaning hole in the bottom of the box. This pipe connection should be long enough to reach outside the building and should be equipped with a steam jet by means of which air can be drawn down through the oxide and discharged outdoors.

If cleaning holes are not provided in the bottom of the purifiers a permanent wrought iron connection can be made either to the inlet pipe or to the bottom of each purifier, these connections being run together into one pipe arranged with a steam jet and outside discharge as above. Either a valve or a water seal must be provided on each connection, the closing or sealing of which will prevent any gas from leaking from the boxes in use and being blown out into the air. The use of water seals instead of valves on these connections is advised by several engineers who have employed this method of revivification, because they found that the valves became clogged, making it difficult to shut them tightly.

When revivifying oxide in this way the cover should be taken off the box before beginning operations, and the temperature of the oxide should be carefully watched to see that it does not rise too high. If it does get dangerously high it can be reduced by wetting the oxide by means of a hose. The temperatures should be taken at different places in the box by thermometers inserted in pipes driven into the oxide.

Care must be taken to make sure that the lid of the cleaning opening, or the valve on a permanent connection, is tightly closed before gas is turned on to a box again after the oxide in it has been revivified. In case a water seal is used instead of a valve, the seal must be filled with water after the operation is finished.

163. If you had a set of purifiers consisting of four 10 ft. × 10 ft. × 4 ft. boxes in which you wished to use

oxide of iron in one layer 3 ft. 0 in. deep in each box, how many bushels of oxide would you buy or make up? The amount given should include not only the oxide actually in the boxes at any one time, but also that which it would be necessary to have on the floor at the same time, to make it certain that each lot of oxide would be afforded the opportunity for complete revivification. Give the reasons for your answer.

Ans. The volume of oxide of iron required to fill a purifying box 10 ft. square to a depth of 3 ft. 0 in. will be $10 \times 10 \times 3 = 300$ cu. ft. Purifying material being measured by the struck bushel, which contains 2,150 cu. in. or 1.24 cu. ft., 300 cu. ft. will be $\frac{300}{1.24} = 242$ bushels, so that each batch of oxide will have to contain 242 bushels.

The number of batches that should be kept in use for a set of four boxes will depend somewhat upon the area of the space available for revivifying purposes. It is very important that the oxide should be fully revivified before it is put back into the purifying box, since if not so revivified it cannot do good work, and any attempt to get along with an insufficient number of batches leads to continuously deteriorating results. Therefore, when it is possible to secure the necessary area, it is best to keep in use eight batches, each box having its own two batches, which are used only in it. This allows each batch to remain on the revivifying floor at least four days, even when the conditions are so bad that it is necessary to change a box every day. If working under better conditions there is still more time for revivification and the oxide is in just that much better shape, since the longer it remains exposed to the air under favorable conditions the more certain it is to be thoroughly revivified.

If it is impossible to secure sufficient area to permit of handling the eight batches, seven or even six can be made to do, although the working will not be as satisfactory as with the larger number. But even under this condition a volume of oxide equivalent to either one or two batches should be kept on hand, in addition to that in actual use, so as to be able to allow a batch that does not revivify in time to be used in its turn, to be set aside and replaced from the stock. It is therefore necessary in the case given to buy, or make up, 8 × 242 = 1,936, or say 1,950 bushels of oxide.

164. What makes spent oxide valuable?

Ans. The two substances whose presence in spent oxide contribute most to its commercial value are Prussian blue and free sulphur, the former being found in oxide which has been used for the purification of coal gas.

The sulphur is removed by treating the material with some solvent for this substance, such as bisulphide of carbon or benzol, until it has been all dissolved, and then evaporating the solution, removing the solvent and leaving the sulphur, which is purified by sublimation.

Prussian blue, ferrocyanide of iron $(Fe(CN)_6)_3\ (Fe_2)_2$ is recovered in the form of yellow prussiate of potash, $K_4Fe(CN)_6$, by treating the spent oxide with caustic potash. The reaction is expressed by the equation $(Fe(CN)_6)_3(Fe_2)_2 + 12KOH = 3K_4Fe(CN)_6 + 2Fe_2O_3.3H_2O$. The yellow prussiate of potash thus formed is crystallized out of the solution resulting from the reaction.

Station Meters.

165. Give a description, illustrated with sketches, of the construction of the drum of a station meter and the manner in which it is mounted in the case and explain how it measures the gas.

Ans. Figure 1 represents the elevation of one of the measuring chambers of the meter drum. One of the partitions "P" is shown, the other being represented by dotted lines. The inlet and outlet passages, which are long narrow openings, shown in section in Figure 3, are indicated by the letters "I" and "O." For the purpose of illustration, we will suppose this vessel to be supported by suitable bearings, placed within a small tank, in which it can freely revolve, the tank being filled with water to the dotted line. As represented, both the inlet "I," in front, and the outlet "O," at the back, are sealed by the water, consequently the air therein cannot

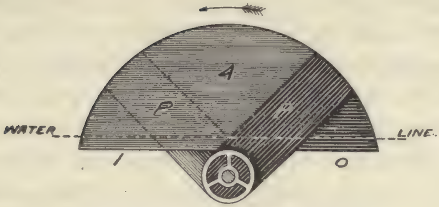


FIG. 1

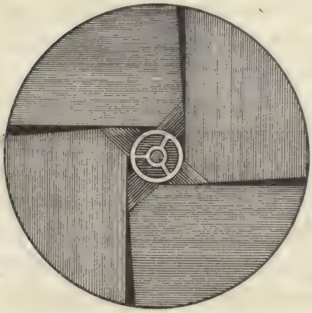


FIG. 2

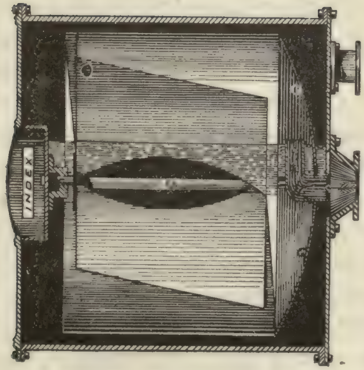


FIG. 3.

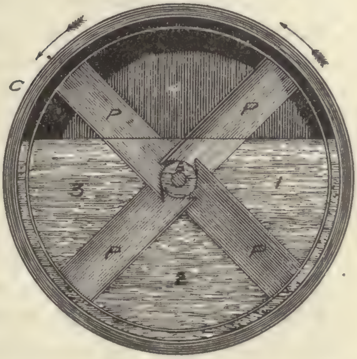


FIG. 4.

STATION METER DRUM.

escape. If now the vessel be slowly turned by the hand in the direction of the arrow, the outlet, "O," will become unsealed, and the air will be gradually expelled and replaced by the water as the vessel is immersed. Continuing the operation, air will enter by the inlet "I," the vessel will gradually rise, and when attaining the position represented will be again filled with air. This is precisely the action which takes place with each chamber of the meter drum, of which there are four attached to one common shaft, each chamber being provided with its corresponding inlet and outlet, and being filled and emptied in succession as described.

Figure 2 is a drawing of a meter drum, either the front or back, showing the passages to the various compartments; but it is evident that if this were placed within the case without the means of separating the inlet from the outlet passages, it would be inoperative. This separation is accomplished by two very simple contrivances, known as the "hollow cover" and "spout," which were the invention of John Malam.

Figure 3 represents the case of a station meter in cross section, with a side view of the drum, which revolves with the axle "a;" it also shows the interior of one of the measuring chambers, the hollow cover "Q," in section, and the spout "r." The hollow cover is a concave disc, soldered round its edges to the drum, and has at its centre a circular orifice through which the spout is admitted. The spout is a bent pipe securely attached to the outer case, but completely isolated from the drum, and enters the hollow cover, its top extending a short distance above the water line. The openings in the centre of the drum are for the purpose of allowing the water to flow freely into and out of the various chambers as the drum revolves; these, as well as the orifice in the hollow cover, are sealed by the water, as shown in the drawing. Thus, the gas entering the meter in the direction of the arrow passes into the hollow cover, whence it is conveyed to the various inlet passages into the respective chambers, and as each of these is filled in rotation, the gas is expelled from the one preceding.

Figure 4 shows another section of the same meter. The case, "C," is charged with water to the required height as indicated. The drum is divided into four distinct measuring chambers, numbered 1, 2, 3 and 4, by means of the partitions "P P P P," which are placed at angles with the line of the axle, for the purpose of diminishing and equalizing their resistance when passing through the water. If the partitions were placed paralled with the axle, the obstruction would be such as to render the instrument uncertain in its registration, on account of the excessive oscillation of the water in the case.

As already represented in Figure 1, the chamber, when in the position of that numbered 4, is filled with gas, its inlet and outlet being both sealed by the water. If we now suppose the meter to be in action, the gas will enter the chamber 1, and when filling will cause the drum to revolve in the direction of the arrows, expelling in the first place the gas from chamber 3, so that when the outlet of 4 rises above the water, the gas will issue from that chamber. In the meantime, the chamber marked 1 gradually rises, increasing in capacity, and when this is nearly full of gas, chamber 2 comes into operation. This action is continuous, all the chambers being filled in rotation, at the same time expelling the gas from those preceding them. Here the method of giving motion to the drum by hand, as proposed when describing Figure 1, is superseded by the force or pressure of the gas; and so long as this is maintained, and any supply issues from the meter, its action is continuous.

Hence the contents of one revolution of the drum being known—say, 20 cu. ft.—it can be readily understood how, by simple gear work, such as wheels and pinions, the quantity of gas passing will be recorded on the index with the most unerring accuracy during a period of many years, depending on the duration of the instrument, and the maintenance of the water-line at the proper height.

When constructing meter drums, their approximate capacity is obtained by calculation; but the exact position of the water-line is ascertained by experiment. It is then carefully marked on the front of the case, so that in the event of the gauge being broken or lost, the mark is always retained. With the same object some manufacturers attach a brass plate to the case, having the words "water-line" engraved thereon;

others have it marked on a brass tube which surrounds the glass of the gauge, a space being left for observation.

The causes of the friction or pressure required to work a meter are not generally understood, hence we find that various appliances have, from time to time, been patented in order to diminish it. Amongst these, glass bearings for the axles have been proposed ; but it must be evident, from the great facility with which a meter wheel revolves in its case when empty, and the difficulty with which it moves when charged, that the cause of the obstruction must be the water.

As already stated, the partitions are placed at angles ; therefore, in revolving in the water, they form a kind of vane or screw, and whilst in action continuously draw a portion of water through the centre opening, which water is expelled at the back of the wheel. A similar result, although in a very slight degree, is effected by the inlet and outlet hoods, in consequence of their angular position. Under these circumstances, therefore, the orifice in the hollow cover should be made as ample as possible, in order that the water may pass freely, its dimensions being of importance in the construction of station meter wheels. Further, in the construction of a meter wheel so that it may work with a minimum of pressure, care should be observed to make the passages communicating between the various chambers of ample capacity at the centre, so that the water may flow freely into and from the chambers during the revolution of the wheel. By inattention to these points, the friction or pressure required to work the meter is materially increased, and by due regard thereto it may be in like manner diminished.

The above description, which is taken from King's Treatise on Coal Gas, is one of a drum made with four partitions, the manner in which all station meter drums were formerly made.

Later, however, several forms of drums with three partitions instead of four were placed on the market. These are built in such a way as to allow the partitions to pass through the water with less friction than is the case with the partitions of drums of the old style, and therefore the three-partition drums can revolve more rapidly and pass more gas without throwing any more pressure.

Still later a four partition drum was patented by Mr. C. W. Hinman, which is so designed that the partitions in it come more nearly to being at right-angles to the water as they pass through it and therefore develop much less friction in going through the water than do the partitions of any of the other styles of drum. For this reason a Hinman drum of a given size has a much greater measuring capacity than any of the styles of drum previously made, and it is superseding, in the United States at any rate, all of the older forms.

The principle of all these drums is, however, the same, so that the description which has been given of the action of the ordinary four-partition drum applies also to them.

166. Why is it important to have the water-line in the drum of a station-meter always at the same level?

Ans. It is important to have the water-line in the drum of a station-meter always at the same level, and at the level at which it stands when the meter registers correctly, because any change of level will make a change in the number of cubic feet registered on the dial for each one thousand cubic feet passing the meter. If the water-line be lowered in the drum, more gas passes for a revolution of the drum, although the amount registered on the dial will remain the same. If the water-line be raised in the drum, less gas passes for each revolution of the drum. Therefore, if the water-line be below the correct level, the meter registers less gas than passes and runs slow; if the water-line be above the correct level the meter registers more gas than passes and runs fast.

167. Describe the testing or proving of a station-meter, giving each step of the work from the putting it out of use in order to test it, to the putting it to work again after it has been tested.

Ans. The meter room should be thoroughly ventilated throughout the test.

The object of testing a station-meter is to determine:

A—Whether there are any leaks in the drum.

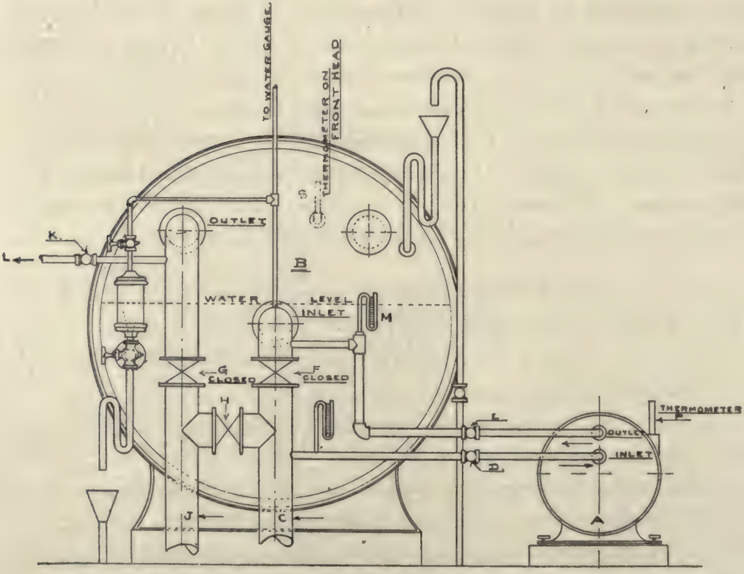
B—If there are no leaks, how many cubic feet of gas are passed for one revolution of the drum.

C—Whether the index registers correctly the number of cubic feet passed through the drum.

Before the meter is put out of use for the purpose of testing it, remove the plate over the dial, thus exposing the spindle that comes through the meter head, stop the meter long enough to attach a pointer to the spindle and make a mark on the case, so that the exact revolutions of the pointer can be counted. Then start the meter and note how much gas is registered on the index for ten to twenty revolutions of the spindle. Calculate from this the number of cubic feet registered for each revolution of the spindle. The use to be made of this figure will be explained later on.

Put the meter out of use by opening the by-pass and closing valves F and G. Pour water into the connections C and J above these valves, to seal the valves. Pet-cocks should be tapped into these pipes above the valves and below the surface of the water, and opened from time to time during the test, to see that these valves remained sealed.

Now the meter is out of use and ready to be tested.



CONNECTIONS FOR PROVING STATION METER.

A—Does the drum leak?

Connect the test meter and iron pipes as shown, and run the pipe L out of doors.

Test the connections of the test meter by opening the cocks D and E and passing a little gas through both meters. Then close the cock K. When the full pressure of the gas shows on both meters, if the index of the test meter remains stationary, the outlet connections and the station meter case and gas connections above valves F and G are gas-tight.

Close cocks D and E. Remove gauge M, and open cock K, and having thus put atmospheric pressure on both inside and outside of the station-meter drum, see that the water in the meter is exactly to the mark on the water gauge and dripping from the automatic overflow, if the meter has this attachment, at the rate that is maintained when the meter is in regular use. Then close K and replace gauge; shut off automatic overflow and close off water supply. Remove the manhole plates on top of station meter; remove one of the plugs in the drum and replace it with a special plug fitted with an eyebolt, attach a rope to the eye-bolt and make the rope fast to prevent the drum turning. Open cock E, then open cock D slowly, thus admitting gas gradually into the station-meter drum until the pressure has increased sufficiently to blow the seals in the meter. The noise of the blowing gas can be heard and the pressure will fluctuate violently. The blowing pressure should be recorded. Now shut D and watch gauge M; if the pressure falls, that section of the drum that is being tested leaks. The size of the leak can be determined by partly opening D, keeping pressure on M below the pressure at which the seals blow and noting the registration of the test meter for, say, ten minutes. Now leave D open and slack the rope until the meter drum has made about one-eighth of a revolution, and repeat the test made above. Repeat this process until the drum has been tested for blowing pressure and for tightness in eight positions. The drum should then have made one revolution.

If the manhole is not available for this test, the spare outlet flange can be removed and the drum blocked in different positions by a piece of scantling.

Before starting to revolve the drum, the position of pointer on spindle on meter front should be accurately marked, and note should be made of the number of revolutions made by the pointer for one revolution of the drum ; this is usually exactly one, or exactly two.

If the drum leaks it must be repaired before test for capacity can be made. Do not attempt to correct for leaks in drum by raising water line.

If the drum is tight, proceed to determine :

B—How many cubic feet of gas are passed by one revolution of the drum ?

Remove the rope, replace plug and manhole, open automatic overflow and water supply pipe. Repeat test for tightness of connections and case.

Open cock K, and adjust the cock D on the test meter inlet until the gas passes at a rate within the limit of the test meter. Then wait until water begins to drip from the automatic overflow.

The gas now passing through both meters, one observer should call out at the instant the pointer on the station meter spindle reaches the mark on the case, and a second observer should, at the same instant, note and record the test meter reading. When the drum has made one complete revolution as indicated by the pointer, note and record the test meter reading as before. The quantity thus registered by the test meter is the quantity of gas passed by one revolution of the station-meter drum. To insure accuracy, at least three revolutions of the drum should be made.

During this test the temperature of the water in the two meters should be as nearly as possible the same as the temperature of the room. If the temperatures of the gas passing through the test meter and through the station meter are different, the volume of the gas passing through the test meter should be corrected to the temperature of the gas passing through the station meter. This can be done by the use of a table for the correction of the volumes of gas at different temperatures.

C—Does the index register correctly the number of cubic feet passed through the drum ?

Count the teeth on the gear wheels connecting the spindle with the meter index and calculate the number of cubic feet registered by one revolution of the meter drum. This figure should agree closely with that obtained at the outset, by calculating from the registration of the meter during twenty revolutions. This latter figure was obtained for the purpose of checking the calculations from the gear wheels. Accept the figure obtained by counting the teeth on the gear wheels as correct.

If the figures obtained by tests B and C are the same, the meter is correct ; if the quantity passed (B) is greater than the quantity registered (C), the meter is slow ; if the contrary, the meter is fast. If the meter is not correct, it is better to change the gears, leaving the water level at the position marked. If inconvenient to have gears changed, alter water line to correct, raising it if meter is slow and lowering if meter is fast, and test again. Only very small errors can be corrected by this method, and it should be used only on small meters.

To put the meter in use again, remove the test meter connections on pipe L, remove the pointer from spindle and replace dial plate, open valves F and G, and close valve H.

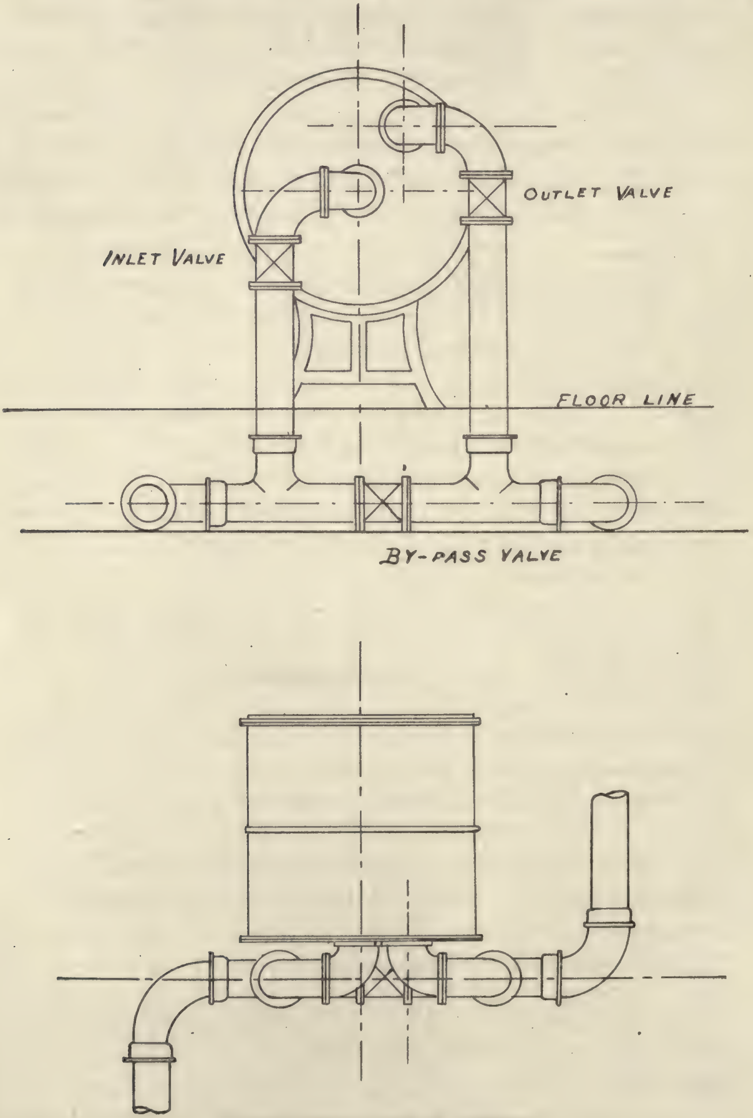
NOTE.—Test meter is preferably a 60 or 80-light wet meter, with a dial registering to one-tenth of a cubic foot. This meter should be carefully tested on a meter prover when passing gas at the same rate as during the station meter test. This can be readily done by maintaining the same difference of pressure between inlet and outlet of test meter, as observed during test B.

The test meter should always be set level.

Test A can be made without a test meter, using a pressure gauge only. A common, dry meter can be used to measure the leakage.

The above is an accurate and scientific, if somewhat difficult, method of proving a station meter. A more simple method is as follows:

To prove the tightness of the drum: Proceed as above down



BY-PASS FOR STATION METER.

to and including the determination of the tightness of case and connections, and the correctness of the water line. Then run gas through both meters at a rate about equal to the maximum capacity of the test meter, and again at half that rate, making the test cover in each case an equal number of, and at least three full, revolutions of the drum of the station meter. If the tests agree, the drum is tight.

This method does not necessitate opening the manhole of the meter.

Determine the capacity of the drum per revolution as above. Count the teeth on the gear wheels, as above, and calculate the number of feet registered by one revolution. If you do not understand the gear wheel and dial combination, test for drum tightness and capacity, as above, disconnect test meter and turn gas through the station meter as if in regular use for twenty revolutions of the drum, as shown on the pointer. See if the dial registers twenty times the determined capacity of the drum. If it does, the meter registers correctly.

168. Give a sketch of a by-pass as connected to a station meter and describe its use and purpose.

Ans. The accompanying cut shows a meter by-pass. The meter may be by-passed for cleaning, repairing, or other purpose, by opening the valve on the horizontal pipe and shutting the valves on the two vertical pipes.

Holders.

169. What are the respective merits of concrete and brick work as the material to be employed in the construction of the walls of gas holder tanks?

Ans. As a material to be employed in building the walls of gas holder tanks, concrete possesses the following advantages over brick work: Its tensile strength is greater and can moreover be easily increased by embedding in the tank wall, as it is built up, rings of hoop iron which may be placed from four to six inches apart horizontally and from five to six feet apart vertically. This greater tensile strength reduces the liability of cracking when the nature of the soil is such as to make it difficult to secure a good earth backing for the wall. A tank can be built of this material without the aid of any but comparatively unskilled labor under proper supervision. It can be made water-tight of itself, by the use of materials free from loam or dirt and the exercise of proper care in mixing and placing in position, while it is almost impossible to build a brick wall that will be water-tight of itself, and in any case the concrete tank can be made tight, either by a backing of clay puddle or by rendering with cement, as easily as can the brick tank. As a general thing concrete is cheaper than brick work, and this is especially the case when cheap broken stone or gravel, or an accumulation of old retort material or bricks are available for aggregate. Well made concrete is not as much affected by exposure to the weather as is even the best brick work, and therefore a concrete tank will not be subject to as much wear at the water line as a brick one. Altogether, unless bricks are cheap and the material for the aggregate of concrete dear, concrete is the best material to use for the walls of holder tanks, where the conditions are such as to permit the economical construction of a masonry tank.

Concrete is used for tank walls much more frequently in England than in this country. Mr. N. H. Humphrys, writing of "Large Gas Holders in England" (American Gas Light Journal, Vol. LXX, page 803) says: "The next direction in which progress has been made is the substitution of cement concrete for brick work, which means a large saving both of material and labor, together with increased strength. Concrete is not only easy of erection, requiring no skilled labor, but it is also stronger than brick. It offers every facility for the incorporation, within its substance, of iron bands, and concrete strengthened with iron ties is in some respects a perfect material. The iron being enclosed is preserved from corrosion or changes of temperature, and we have the weight and rigidity of the masonry tank, combined with the strength of the iron tank, without the inelastic brittleness of the one and the contraction and expansion of the other. Gas works are continually producing large quantities of hard clinker, broken brick, old retorts, etc., that are very suitable for aggregate, but which only realize low prices if offered for sale. By exercising a little foresight, sufficient material can be saved up in the course of a few years to supply all that is wanted."

170. Having selected concrete as the material for the wall of a gas holder tank, describe the method that you would adopt to build up the wall and insure its being water-tight.

Ans. Various methods may be adopted for building a tank wall of concrete. When, as is usual, a trench is excavated around the whole circumference of the tank with an outer diameter greater than that of the outer faces of the piers, it is customary to use wooden forms made to the proper curve, one concave for the outer face and one convex for the inner face of the wall, from 2 feet 6 inches to 3 feet high, and of a convenient length, usually that between two piers. These forms being set on the circumferences of the outer and inner faces of the wall, and properly supported and braced, the concrete is put in place between them and thoroughly tamped. When it has become sufficiently set, the forms are moved to the portion of the wall that is to be next made. For the piers, rectangular boxes of the proper size are used in the same manner. A paper read by Mr. C. W. Andrews, before the Ohio Gas Light Association, in 1899 (American Gas Light Journal, Vol. LXX, page 445; Progressive Age, Vol. XVII, page 125), describes very fully the construction of a concrete tank by this method, and should be read by the students.

When the ground is firm and can be securely held by timbering, laid out so that small sections of it can be removed just ahead of the concrete work, as the wall is built up, the outer edge of the excavation can be made vertical and to the proper circle for the outside of the wall at its base, and the concrete tamped between the earth and an inner form. In this way a backing of undisturbed earth is obtained at the bottom of the wall that must of necessity be much more solid than any back filling. When the offset in the wall is reached, an outer form must be used, and the space between wall and earth filled in as usual, but even here the space to be filled is much smaller and the backing that much stronger.

Mr. V. Wyatt, an English constructing gas engineer of great experience, advocated and used a method for building the walls of large tanks in concrete blocks of the full vertical height of the wall and with radial sides. Each pier formed one block, and each bay between the piers was divided into three. The idea was that, it being cheaper to sink, say, 48 comparatively small pits than it was to dig and brace a large circular trench, there would be a saving in the cost of the tank. The piers were first put in, the work being carried on on all four quarters of the circle at the same time, then the blocks forming the centres of the bays, and then the two blocks necessary to complete each bay. In each case the excavation was made of just the right shape and size for the wall at the bottom, and timbered in such a way that sections of the timbering three feet high could be removed as the concrete was put in, and the concrete put in in layers three feet deep, filling up the whole space of the excavation at the bottom. When the offset at the back of the wall was reached, a form was used for the back and the concrete tamped between this form and the inner face of the excavation, the space occupied by the form being afterward filled in with earth tightly tamped. All of the sections were made with radial sides and keyed into each other to prevent leakage. Thus the wall, when finished, was a circular arch formed of large blocks. Hoop iron was used, as indicated in the answer to question No. 169, the ends being left projecting and turned up in the piers and centre blocks to be turned down and built in the connecting blocks, thus forming a bond between the blocks. After the wall was finished, the excavation of the centre was carried on without any need of timbering. Mr. Wyatt's paper can be found in the American Gas Light Journal, Vol. L, page 655.

In this case the wall was made water-tight by a lining of 9 in. of brickwork, built so as to leave a space of 2 in. between the outer circumference of the brickwork and the inner circumference of the concrete, this space being grouted with Portland cement as the wall was built.

However, if care is taken to use nothing but sharp, washed sand for the mortar, and for the aggregate materials free from loam and dirt, and of such size or sizes as to prevent the existence of any large spaces between the different pieces, and if the mortar and aggregate are in proper proportions and well mixed, and the concrete is put into place carefully and well tamped, the wall will be water-tight without any further treatment.

If these precautions are not taken, the wall should be rendered with $\frac{1}{4}$ in. to $\frac{1}{2}$ in. of neat Portland cement, or lined and grouted as above. The lining, while it is more expensive, protects the cement from the action of the water in the tank and the weather, and thus prevents any cracking and possible leakage. Such a lining should, of course, be tied to the concrete wall at proper intervals.

171. What kind of bricks are best for holder tank work ?

Ans. Baker's Treatise on Masonry Construction contains the following paragraph : "Requisites for Good Brick. 1. A good brick should have plane faces, parallel sides, and sharp edges and angles. 2. It should be of fine, compact, uniform texture ; should be quite hard, and should have a clear ringing sound when struck a sharp blow. 3. It should not absorb more than one-tenth of its weight of water. 4. Its specific gravity should be two or more. 5. The crushing strength of half brick, when ground flat and pressed between thick metal plates, should be at least 7,000 pounds per square inch."

For holder tank construction it is especially important that the brick should be strong, hard and dense. While all twisted or distorted brick should be refused from tank construction, it is not essential that the faces should be exactly parallel. A slight bulge or belly to the larger surfaces of the brick is not a fault. Such a brick when shoved into place, as described in answer to question No. 172, is much more certain to force out all the air and insure a well filled joint than a brick that is hollow on the faces or, even, than a brick that is exactly flat, with parallel faces.

Brick for a holder tank should not be bought on a sample. The kiln from which the brick is to be purchased should be examined, if possible, and if not, the bricks should be seen in large numbers before purchase is made.

Some holder tanks depend for their tightness upon a filling of clay under the bottom and back of the side, the brick being intended to give form to the tank, support the puddle and guide the holder. Such a tank may appropriately be made of porous brick, provided the brick has sufficient strength, for there is no objection to the water percolating through the brick and coming in contact with the clay outside. In fact, it is important, with such tanks, that this should be the condition. Where, however, the tank depends for its tightness upon the brick work, the brick should be dense.

172. Describe the proper method of laying brick in holder tank work.

Ans. Baker's Treatise on Masonry Construction gives the following instructions: "Brick should not be merely laid, but every one should be rubbed and pressed down in such a manner as to force the mortar into the pores of the bricks and produce the maximum adhesion; with quick-setting cement this is still more important than with lime mortar. For the best work it is specified that the brick shall be laid with a 'shove joint;' that is, the brick shall first be laid so as to project over the one below, and be pressed into the mortar and then be shoved into its final position.

"Since bricks have great avidity for water, it is best to dampen them before laying. If the mortar is stiff and the brick dry, the latter absorb the water so rapidly that the mortar does not set properly and will crumble in the fingers when dry. Neglect in this particular is the cause of most of the failures of brick work. * * * * * Wetting the brick before laying will also remove the dust from the surface, which otherwise would prevent perfect adhesion."

There is among constructors a difference of opinion as to how the bricks should be put into the wall. The following is from a man who has had considerable experience in tank work, and whose tanks have been tight:

"The bricklayer should put only enough mortar on the wall to embed one brick, place the brick in the mortar, then give it a sliding motion in two directions to fill the joints on one end and on one side, and to expel the air from under the brick. The mortar should then be cut off the top and returned to the board.

"It is impossible to accurately describe how to push brick; the only way is to get a brick mason that can and will do this kind of work and have him instruct each mason that is taken on the job how the work is to be done."

An advocate of grouting, who has been perfectly successful in tank work, writes as follows: "The thickness of joint being decided upon, the outside and inside circle should be laid up five courses, making a trough for filling in. Spread thick mortar in the bottom of this trough and lay the brick in this mortar, care being taken that the bricks shall be put down in such a manner as to drive all the air out as they fall into place. This makes a full joint under the brick. Then grout with mortar to be thrown over the tops of these bricks from a bucket in the same manner as coke is quenched, the mason using his trowel to fill in any joints that are not filled by spreading the mortar in this way. On this layer of bricks spread another layer of stiff mortar and lay another course of brick, grouting in these as in the former case. Care should be taken to arrange headers and stretchers, so that there will be a good bond.

"By pursuing this method a fair mason can lay from 1,800 to 2,200 brick per day; 2,100 to 2,200 brick were laid per day, per mason, under my supervision. The brick for the inside and outside circle should be wetted with a hose. The brick for filling in should be thoroughly wetted, and I would advise having a number of tubs placed at intervals on the scaffold, and the brick thoroughly soaked with water in these tubs before being put in the wall; in fact, the brick should be taken from the tubs and placed in the wall without giving them any time to dry."

There can be no doubt that entirely satisfactory tanks have been built by each method. It is probably equally true that a mason can lay from 200 to 400 more bricks a day by adopting the second or grouting method. It is also probably true that more close supervision is required to obtain good work with the grouting system.

173. What is meant by the statement, "The tank was rendered with neat cement"? What circumstances call for the rendering with cement of a brick tank for a gasholder?

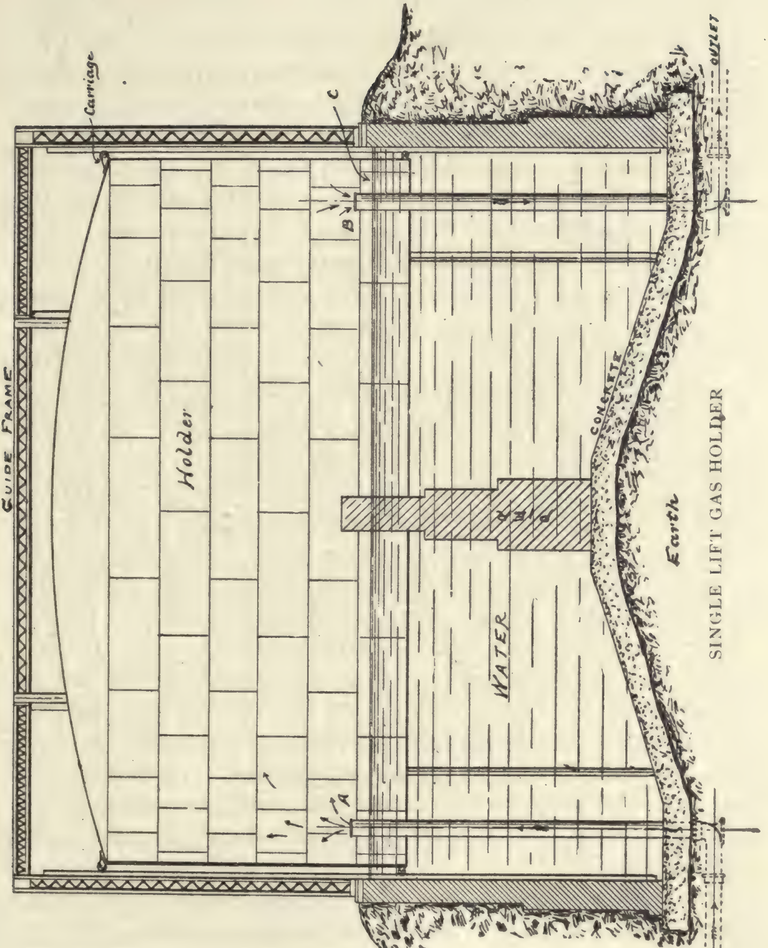
Ans. To "render" a wall is to plaster directly upon the wall, without the use of lathing. Technically it is to apply one coat.

"Neat cement" means cement unmixed, free from adulteration. Therefore, the statement, "The tank was rendered with neat cement" means that the wall and bottom were covered with one coat of a mixture of cement and water, without sand, applied directly to the masonry.

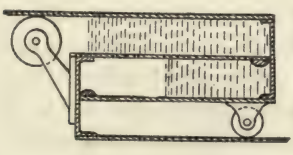
A brick tank for a gasholder would be rendered with cement to make it watertight when the local conditions were such as to cause to be excessive the cost of securing this tightness by means of a backing of clay puddle put immediately outside the wall as well as under the foundations and the bottom of the tank. If not too expensive, the use of clay puddle is preferable to rendering with cement, because when a holder-tank is made tight by puddle the contained water soaks through the brickwork and exerts its pressure upon the backing and not upon the wall, as it does when the wall is rendered on the inside, and the wall being relieved of the pressure is not so apt to crack.

174. Describe the construction and action of both a single lift gas holder and a telescopic holder. Make sketches to illustrate your descriptions.

Ans. "A gas holder consists of a tank generally built of brickwork or steel, and containing water, and a cylindrical vessel made of wrought iron sheets, open at the bottom but closed on top, and so guided in the tank and along columns rising above the tank as to work freely up and down. This guiding is performed by rollers or wheels attached at equal distances around the top and bottom of the cylinder, working



SINGLE LIFT GAS HOLDER



CUP AND GRIP.

against rails or channel irons fastened to the inside of the tank wall and to the columns. The tops of the columns are joined by girders. Gas is admitted to and drawn from the cylindrical vessel or holder proper by pipes passing down under the foundation of the tank and up to a point above the water level. When gas is admitted to the holder through the inlet pipe it enters the space between the closed top or roof and the water which seals the open bottom. As the gas enters, the pressure increases until it is sufficient to overcome the weight of the holder, which then begins to rise and continues to do so as long as gas is entering. Gas is drawn out by opening the outlet valve, when the weight of the holder forces the gas out and the holder falls. When gas is being sent into and drawn from the holder at the same time, the holder will rise when the volume of gas entering is greater than that leaving it, and fall when this condition is reversed.''

In a ''telescopic'' holder the inner section is exactly the same as a single lift holder, except that it is finished at the bottom with a ''cup'' instead of an angle iron ''curb.'' The ''cup'' is an annular trough, the inner side being formed by the bottom sheet of the inner section, and is usually rectangular in cross section. Its construction is shown by the cut. The outer sections are merely cylindrical shells of larger diameter than the inner section, and of about the same height. At the top is fastened a ''grip'' which is the same as a cup turned upside down, as shown on the cut. The bottom is finished with another ''cup'' if the section is an intermediate one in a series, or with a ''curb'' if it is the outside one of the series.

The action of the inner section is similar to that of a single lift holder. When this section is completely filled with gas the cup filled with water engages the grip of the next section, and as gas continues to flow into the holder, raises this section, the water in the cup forming a seal which prevents the escape of any gas. When the holder descends after both sections have been raised, the outer section lands on the bottom, and the inner section continuing to go down, the cup and grip separate, and the action is again that of a single lift holder.

The cups of telescopic holders are guided by wheels bearing against plates riveted on the sides of the outer sections, the grips of the outer sections are guided by wheels bearing against the guide framing, the height of which is usually made equal to the combined height of all the sections, and the curb of the outermost section is guided by wheels bearing on rails or plates fastened to the tank wall.

The capacity of a two lift telescopic holder is double that of a single lift holder of the same diameter, that of a three lift three times that of a single lift, and so on.

175. The inner section of a two-lift gas holder has a diameter of 87 ft. and a height of 20 ft., and the outer section has the same height and a diameter of 89 ft. The cup is 16 in. deep. The holder is contained in a brick tank 91 ft. in diameter and 21 ft. deep from water line to bottom. In the tank is a "cone" which has a height of 15 ft., a diameter of 30 ft. at the top and one of 81 ft. at the bottom. How many gallons of water will be required to fill the tank to the water line and what will be the working capacity of the holder in cubic feet? Give your calculations.

Ans. The volume of the space in the holder tank which will be occupied by water is equal to the difference between the volume of a cylinder, having a diameter equal to that of the tank and a height equal to the height of the tank from the bottom up to the water line, and the volume of a frustrum of a cone of the dimensions of the "cone" in the tank. The volume of a cylinder is equal to the product obtained by multiplying the area of the base by the height. A circle 91 ft. in diameter has an area of 6503.9 sq. ft. The distance from the bottom of the tank to the water line is 21 ft., so the volume of the cylinder formed by the tank is 6503.9 × 21 = 136,581.9 cu. ft. The volume of a frustrum of a cone is equal to the product obtained by multiplying the sum of the areas of the two bases and of a mean proportional between these two bases by one-third the altitude. In this particular case the lower base of the cone has a diameter of 81 ft. and an area of 5,153 sq. ft., and the upper base has a diameter of 30 ft. and an area of 706.9 sq. ft. The mean proportional between these areas is therefore $\sqrt{706.9 \times 5153} = 1908.5$, and the sum of the two areas and this mean proportional is 7768.4 sq. ft. The altitude of the frustrum is 15 ft., hence the volume is $7768.4 \times 5 = 38,842$ cu. ft. To fill the tank to the water line will require $136,581.9 - 38,842 = 97,739.9$ cu. ft., or $97,739.9 \times 7.48 = 731,094$ gallons of water.

The working capacity of the holder will be equal to the volume of the cylindrical portion of the inner section, the gas in the space under the crown above this cylindrical portion not being available for use, plus the volume of that portion of the outer section that is not lapped by the inner section, nor required to be kept below the water level in order to avoid any danger of the gas blowing out from under the bottom curb. The cup being 16 in. deep, and safety requiring that the bottom of the outer section should always be kept 12 in. below the water level, the working height of the outer section will be 2 ft. 4 in., or 2.33 ft. less than its total height. The total height being 20 ft., the working height is 17.67 ft. The diameter of the inner section being 87 ft., the volume is equal to 5944.7 (the area of a circle 87 ft. in diameter) $\times 20 = 118,894$ cu. ft. The diameter of the outer section being 89 ft., the working volume of this section is equal to 6221.1 (the area of a circle 89 ft. in diameter) $\times 17.67 = 109,927$ cu. ft. The working capacity of the holder is therefore 228,821 cu. ft.

176. A two-lift gas holder, the upper section of which is 150 ft. in diameter, gives a pressure of 3.5 in. when uncupped, and one of 5 in. when cupped. What is the weight of each of the sections? Give your calculations.

Ans. The pressure thrown by a gas holder, as measured in inches of water by a syphon gauge, is the height, in inches, of the column of water that is balanced by the weight of the holder. As the pressure acts on each unit of area of the holder crown, the weight of the holder is equal to the product obtained by multiplying the area of its crown by the weight of a column of water, having a height equal to the pressure thrown by the holder and an area equal to the unit used in expressing the area of the crown. Each inch of pressure will represent a weight of 5.208 lb. per sq. ft., or 0.036 lb. per sq. in. since a cubic foot of water weighs 62.5, and therefore a column of water one square foot in area and one inch high will weigh $\frac{62.5}{12} = 5.208$ lb. and a column of water one square inch in area and one inch high will weigh $\frac{62.5}{1728} = 0.036$ pounds.

In the example given, the holder has a diameter of 150 ft. The area of a circle being equal to the square of its diameter multiplied by 0.7854, the area of the crown is 150 ft. × 150 ft. × 0.7854 $\doteq$ 17671.46 sq. ft. The pressure thrown when the holder is uncupped, that is, when the upper or inner section alone is working, is 3.5 in. The weight of this section is therefore $17671.46 \times 5.208 \times 3.5 = 17671.46 \times 18.228 =$ 322,115 lb.

In the same way the weight of the two sections together is equal to $17671.46 \times 5.208 \times 5 = 17671.46 \times 26.040 =$ 460,165 lb.

The weight of the outer section will be $460,165 - 322,115 =$ 138,050 lb.

In the Handbooks for Gas Engineers, tables are given showing the weights in pounds corresponding to each $\frac{1}{10}$ in. of pressure thrown by gas holders of different diameters from 20 ft. to 150 ft. The weight of any given holder can be obtained by multiplying the number found opposite the diameter of the holder in these tables by the pressure thrown expressed in tenths of an inch. The figure given in the table for a holder 150 ft. in diameter is 9,205 and this multiplied by 35 and 50, gives 322,175 lb. and 460,250 lb. as the respective weights of the upper section alone and of both sections combined. The difference between the weights obtained by the two methods is probably due to a greater number of decimal places having been used in making the calculations by which the tabular numbers are obtained than were used in the calculations given in the first part of this answer.

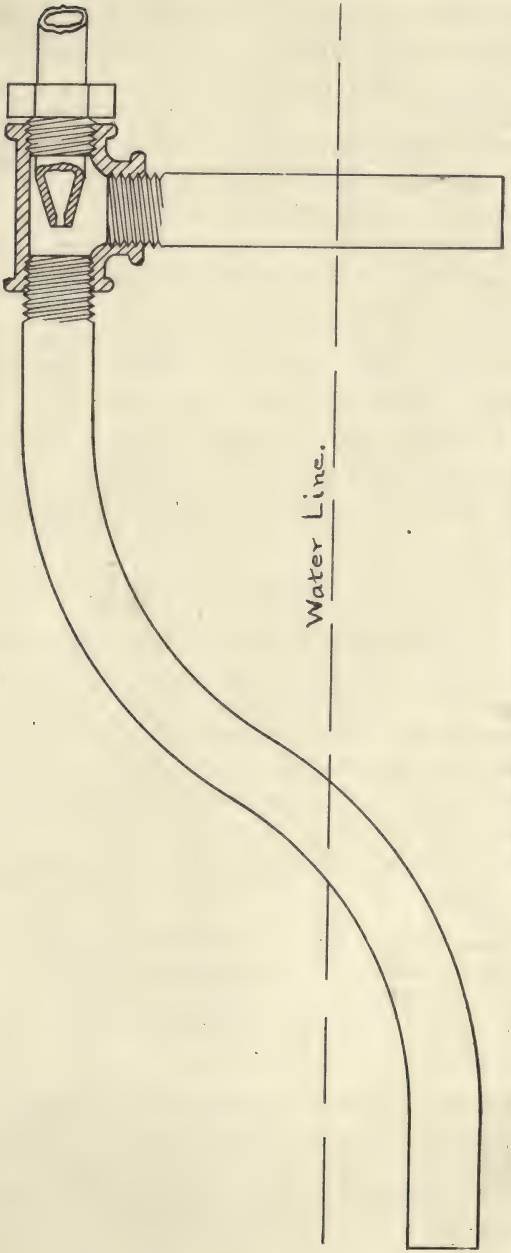
177. A gas holder is 125 ft. in diameter, and gives three inches pressure when full. How much more would it have to weigh to give four inches pressure?

Ans. It is evident that a holder throwing three inches pressure when full must have added to it, to throw four inches pressure when full, a weight equal to a cylinder of water having the diameter of the holder and a depth of one inch. The holder in question being 125 ft. in diameter has an area of 125 × 125 × 0.7854, or 12,271.87 sq. ft. A body of water having an area of one square foot and a depth of one inch weighs one-twelfth as much as a cubic foot of water, or 5.208 lb. which, multiplied by the area of the holder, 12,271.87, will give the weight of water that would cover the holder one inch deep, or 63,912 lb.

A cubic foot of water has been taken as weighing 62.5 lb., in solving the above problem, because although a cubic foot of distilled water, at 60° temperature and 30 inches mercury, weighs 62.355 lb. the commonly accepted weight is 62.5 lb.

178. Give a description, illustrated with sketches, of some form of steam jet that will give good results, when applied to keep the water in the tanks or the cups of gas holders free from ice.

Ans. A very good form of steam jet that can be made from ordinary pipe and fittings is illustrated on the cut. The only fittings needed are a 1 in. tee and a ¾ in. x 1 in. or a ½ in. x 1 in. bushing. Into one of the openings on the run of the tee is screwed either a ¾ in. or ½ in. steam pipe, with its end drawn down to a jet opening not more than ⅛ in. in diameter. When screwed into the tee, the end of this steam pipe should project a little past the centre of the tee. A piece of 1 in. pipe about 18 in. long and offset about 6 in. is screwed into the other outlet on the run. Another piece of 1 in. pipe, from 6 in. to 8 in. long, is screwed into the side outlet. When placed in position for work, the tee is set just above the water line in the holder tank or cup, with its run horizontal and the side outlet looking down. The open end of the nipple in this outlet and that of the offset piece are both below the surface



STEAM JET FOR HOLDER TANKS AND CUPS.

of the water. When the steam is turned on, the jet issuing from the orifice creates a vacuum in the side outlet nipple, and the water rises in this nipple and is blown along with the steam through the offset piece. Thus this jet not only heats the water, but also induces a rapid circulation around the tank or cup, as the case may be, and is therefore much more effective than a jet which merely blows the steam into the water, since water will not freeze as quickly when in comparatively rapid motion as it will when almost at rest.

179. Describe the painting of a gas holder, giving each detail of the work, and including the preparation of the iron by removal of old paint and rust.

Ans. The crown of the holder should be scraped and painted before beginning the work on the sides. Brush over thoroughly with wire brushes, notice the seams and rivets particularly, and brush thoroughly around and between the rivets. Where the old paint is scaly, blistered, or in thick lumps, scrape the surface with chisels or scrapers. Do not let the men skip from one place to another, finish each sheet before beginning another. On the crown begin at the centre and work outward. When the cleaning is done, and when ready to paint, sweep the surface with brooms and apply paint. Work it on as thin as possible, and apply two thin coats in preference to a single thick coat. Be sure the first coat is dry before starting the second.

If leaks are found they should be stopped before the painting is begun.

The cleaning of the sides of a holder will depend upon the conditions at the works. If the holder can be put out of use, the cleaning and painting can proceed uninterruptedly. If the holder remains in use the work will proceed as opportunity offers.

In cleaning begin at the top row of sheets and work down. If possible, provide a sufficient number of men to do the cleaning as the holder rises. If this is not practicable, arrange your force to cover one-half, or any other fraction of the circumference, at one time.

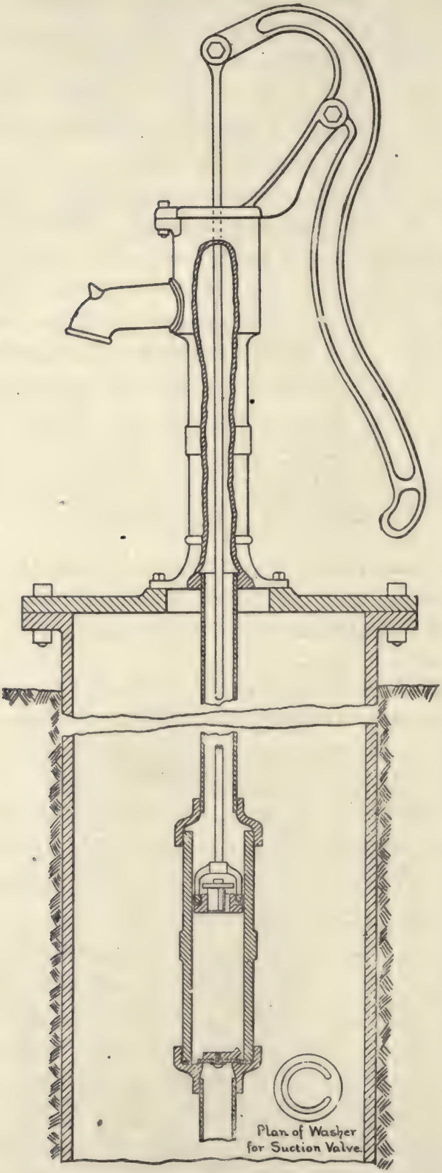
Provide scrapers, brooms and brushes with short and long handles. Short ladders will also be found convenient at times. There should be no hurrying, and the foreman should inspect and pass upon each sheet as it is cleaned before the workman changes to another sheet, Faults are located more certainly this way than by inspecting at intervals.

Do not paint until the cleaning is finished for the day. Then begin at the top and work down. When the upper sheets are being painted the holder will be nearly grounded. It can be made to rise very slowly, so that by the time any course of sheets is, say, five feet above the water, the surface is thoroughly dry. The paint should be worked well in as it is applied. The paint should not run. Only such sheets as can stay above water at least three hours should be painted. When the bottom sheets are reached, have the holder up in the morning nearly to blowing, and keep it up as long as possible, so that the paint can dry thoroughly.

180. Give a description, illustrated with sketches, of some form of hand pump used for pumping the drips on the inlet and outlet pipes of gasholders in brick tanks.

Ans. As the drips on the inlet and outlet pipes of gas holders in brick tanks are usually so far below the surface of the ground that an ordinary suction pump placed at the ground level would have too long a suction pipe to work satisfactorily, it is customary to use a form of deep well pump for pumping them. This kind of pump has the further advantage of being removed from any danger of freezing, so that it is not necessary to protect it from cold.

A form of deep well pump that is frequently used for gas holder drips is shown on the accompanying cut. The pump proper consists of a cylindrical cast iron barrel, of suitable diameter and length, threaded at each end to receive caps similar in form to reducing couplings, these caps being threaded both to screw on the barrel and to receive a pipe of the desired size. The interior of the barrel is bored true. The piston is made in two parts, an upper and a lower. The upper part is an internally threaded ring provided with a



PUMP FOR GASHOLDER DRIPS.

yoke tapped for the insertion of the piston rod. On the outside the lower part of this ring is turned down to form a recess into which the upturned edge of a leather washer can fit. The lower part is in form like a bushing, but has no internal thread. The portion having the smaller diameter is threaded externally to fit the internal thread of the upper part of the piston, and its end is finished to furnish a seat for a cast iron poppet valve. These parts of the piston are not finished and have a little smaller diameter than the barrel, but the piston is made to work air- and water-tight in the barrel by a leather washer held between the two parts, and of such a diameter as to be turned up into the recess in the upper part when the piston is pushed into the barrel. When turned up in this way the tendency to flatten out keeps it pressed tightly against the wall of the barrel. In putting the piston together the valve is put in place on top of the lower part, the leather washer is put on outside of the threaded portion of this part, and the two parts are then screwed together, the washer being held between them.

The bottom valve is formed by a leather washer cut to the shape shown on the cut. The outer ring of leather is held between the lower end of the barrel and the bottom cap, and the flap, weighted with a small circular cast iron weight fastened to it by a round-headed screw and washer, acts as the valve, the narrow neck serving as a hinge. The lower cap is made with a raised ring finished to furnish a seat for this valve.

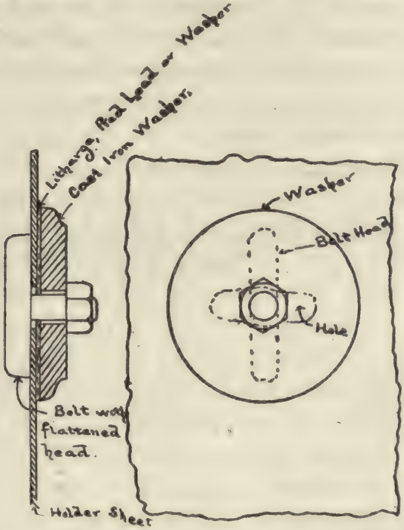
This pump is placed at any convenient height in the inlet or outlet pipe, being usually set from five to ten feet above the bottom of the drip, a suction pipe being run from the lower end to the bottom of the drip and a discharge pipe from the upper end to the base of the stand which forms the external discharge pipe and furnishes a support for the handle by means of which the piston is moved up and down. This stand is in appearance exactly like an ordinary suction pump, but, of course, contains neither piston nor valves, being as stated simply a continuation of the discharge pipe. Its base is threaded internally to receive the pipe coming up from the pump barrel, and is provided with a flange by which it is bolted to the flange covering the top of the inlet or outlet pipe. This cover flange is provided in the centre with a circular hole through which the pump can be put in or taken out in case it is necessary to repair it.

Before being put into the pipe the suction pipe is screwed to the pump, the piston rod, which may be either a rod or a pipe, is made the proper length, the discharge pipe screwed to the pump and then to the base of the stand, the piston rod fastened to the pump handle, and the whole thing is then put into place with the pump, supported from the stand, inside the pipe and at the desired height above the bottom of the drip.

A small hole should be drilled in the discharge pipe just above the pump, so that when pumping is stopped, the water in the stand and in the discharge pipe above this hole will run out and all danger of its freezing be avoided. A means of testing the working of the pump should also be provided by putting in a small pipe opening above the cover flange and running down into the drip to a point say 2 in. above the lower end of the suction pipe. The upper end of this pipe being closed by a stopcock, this stopcock is opened when the pump ceases to raise water. If gas blows when this is done the drip is dry, if it does not the pump is out of order and should be repaired.

181. Give a description, illustrated by a sketch, of the manner in which to stop a small ragged hole in a gas holder sheet too thin to permit of tapping a thread.

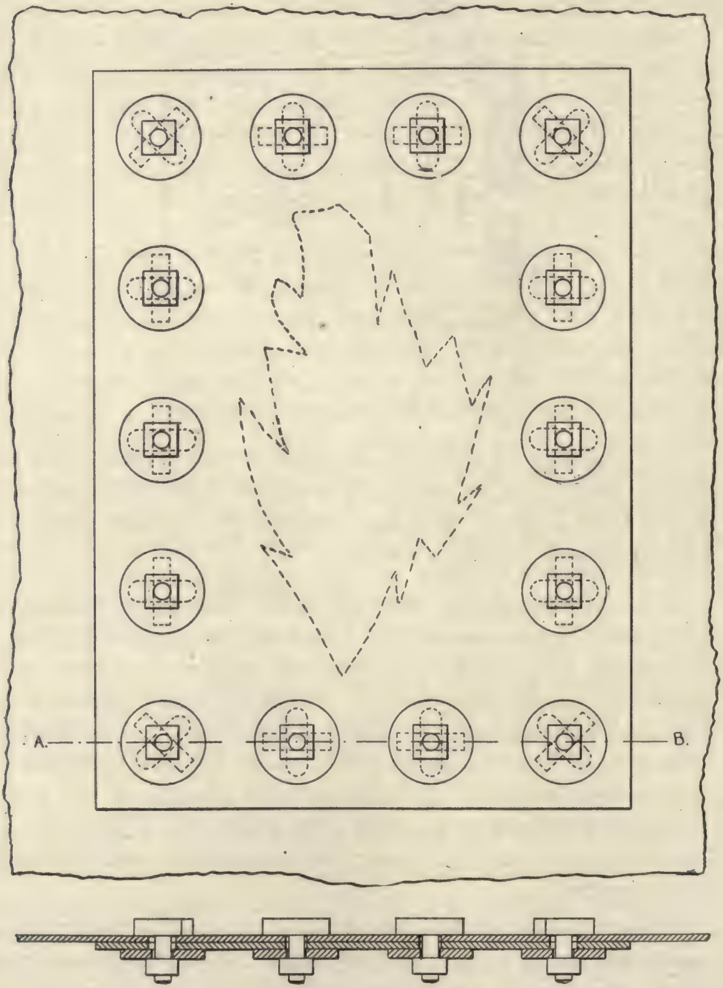
Ans. Make the hole oblong, say 1 in. to $1\frac{1}{8}$ in. long by $\frac{5}{16}$ in. wide. Flatten the head of a $\frac{1}{4}$ in. bolt until it is only $\frac{1}{4}$ in. wide. Make a cast iron or other washer, 2 in. in diameter, with the hole a tight fit over the bolt. Mix a stiff paste of glycerine and litharge, red lead or any similar substance. Tie a string to the bolt, put the flattened head through the hole, give it a quarter turn, slip the washer coated with the paste over the bolt, grummet this with lamp wick, screw down the nut until everything is drawn up tight, saw off the projecting end of the bolt, and the job is complete.



182. Give a description, illustrated with sketches, of the way in which you would patch a ragged hole, too large to be stopped by a single bolt and washer, in a holder sheet too thin to permit tapping a thread.

Ans. Although the finished work would be the same in every case, the temporary measures adopted to prevent loss of gas while the preliminary work of preparation was being carried on would depend upon the location and character of the hole to be patched. If this is in the crown a plate smeared with clay or putty of some kind can be laid over the opening and weighted down. If the hole is in the side of the holder and is small it can be stopped with waste, but if large it may be necessary to keep it under water until the patch is ready to be applied.

This patch should be made of wrought iron or steel plate of about the same weight as the holder sheet, the piece taken being cut of such size and shape as to extend well beyond the edges of the hole on all sides. Oblong holes, say, 1 in. long by $\frac{5}{16}$ in. wide, with the long axis at right angles to the edge of the plate, about 2 in. apart and with ½ in. space between the outer ends of the holes and the edge of the plate, should be made all around the perimeter of the patch. The heads of a sufficient number of ¼ in. bolts should be flattened until they are only ¼ in. wide. The patch should then be applied to,



Section along Line AB.

COMPLETED PATCH OVER RAGGED HOLE IN HOLDER SHEET TOO THIN TO TAP.

and held against, the sheet over the hole until bolt holes are made in the sheet to correspond with those in two diagonally opposite corners of the patch. It can then be bolted temporarily to the sheet by passing the flattened head of one of the prepared bolts through each hole, giving the bolt a quarter turn so as to bring the head at right angles to the hole, placing a washer over the end of the bolt and screwing down the nut. (A string should be tied to the bolt in order to hold it while the nut is being screwed on.) Putty can then be smeared around the edge of the patch to stop the escape of gas and the work of making the other holes in the sheet proceeded with. These holes can be made by means of a breast drill and a round file, or in any other convenient way that will not bend in the sheet around the edges of them, and as each one is made it can be stopped with waste. When the holes are all made the patch should be unbolted and removed, another piece of iron being pressed against the opening to prevent the escape of gas, and a putty made of equal parts of red lead and litharge mixed in glycerine spread over the side that goes against the holder. It is then re-applied to the holder and bolted on permanently, the hole around each bolt being filled in with putty before the washer is put on and a grummet of lamp wick smeared in the putty being used under both the washer and the nut. The washers used should not be less than 1¼ in. in diameter, in order to lap over the hole in its longest dimension. Care must be taken to use bolts on which the nuts turn easily, so that there will be no trouble from the nut and bolt turning together before the nut comes down tight on the patch.

If the patch is a large one applied to the side of the holder it will be well to provide some means of holding it up until it is held by the bolts. This can be done by an eye bolt fastened by nuts on each side of the plate, the eye and the piece of the bolt projecting beyond the outside nut being sawed off when the job is finished.

183. Describe some method by which accumulations of

naphthalene may be completely removed from the inlet pipes of gas holders.

Ans. Accumulations of naphthalene in the inlet pipes of gas holders occur most frequently in that portion of the pipe which passes down under the tank wall and up inside the holder. When the naphthalene exists in the pipe as a flocculent lining of approximately uniform thickness throughout a large portion of its length, it can be removed by charging the gas with the vapor of light naphtha, gas so charged being able to pick up naphthalene deposited in the form of loose crystals. The gas can be charged with the vapor either by injecting the naphtha into the inlet pipe in the form of a spray by means of a steam jet, or by filling the drip at the bottom of the pipe with naphtha which gradually evaporates into the gas passing over it. Naphthalene in the condition named can also be removed by blowing steam into the pipe in sufficient quantity to raise the temperature to the point at which the naphthalene will either melt and run down into the drip, from which it can be pumped out, or vaporize and be taken up by the gas. In all of these methods it is necessary to have gas flowing through the pipes so that the naphthalene as it is vaporized will be picked up by the gas and carried along with it out of the pipe, and there is always danger that the naphthalene so picked up will be again deposited at an inconvenient point during the further travel of the gas. When naphtha vapor is employed this will condense at the same time that the naphthalene is deposited, dissolve the latter and carry it along to the nearest drip, thus preventing any obstruction, but when steam is used the liability is great that the obstruction will be merely transferred from one point of the pipe system to another.

In many cases the presence of naphthalene is not suspected until it has formed, on the inside of the portion of the pipe which rises through the water in the tank, a layer of such thickness that it is detached from the sides of the pipe by its own weight and falls into the elbow making the turn from the vertical into the horizontal part running under the tank wall, where it forms a compact mass. Such a mass seems to be very little affected by either naphtha vapor or steam, and must be washed out either with hot water or with naphtha in the liquid form. Hot water may be used in several ways. At one works, the water, heated by means of steam in an old boiler equipped for the purpose, the pressure being run up to between thirty and forty pounds per square inch, was conducted to the holder by a temporary line of pipe. The operation of cleaning out the holder inlet was carried on as follows: The holder was practically emptied of gas, the time chosen being that when the stock of gas was small enough to be contained in the other holders, and kept so as long as possible, though this was merely to keep the weight of pipe to be handled at a minimum, as the holder could be raised through the outlet pipe without interfering with the work. Through a hole drilled in the top of the bonnet over the inlet pipe was inserted a one-inch pipe on the bottom of which was screwed a 1 in. by ½ in. ell, the direction in which this ell pointed being marked on the pipe at the top. This pipe was made long enough at the start to reach down to the bottom of the holder inlet and a number of short pieces of pipe were provided to screw on as the holder rose. The pipe fitted loosely in the hole in the bonnet, but a practically gas-tight joint was made by wet cloths wound round the pipe at this point. The pipe was supported and turned by means of a bar handle clamped on at the proper height. A hose connection being made between this pipe and that from the hot water heater and the water being turned on, it issued from the opening in the ell in a jet which broke up and dissolved the naphthalene and ran down into the drip, from which it was pumped, bringing the naphthalene with it both in solution and in suspension. The drip pump was kept working all the time the water was being run in, so that the water should be pumped out before it cooled down and dropped the naphthalene. The water pipe being turned so that the stream played against all parts of the inlet pipe, a very complete cleaning could be given by this method.

Another method for washing out the naphthalene is called "plunging." In this the inlet pipe is sealed with water. the flange at the top of the vertical pipe outside the holder taken off and the drip pump removed. The pipe is then filled as full of hot water as it is possible to have it without filling up the horizontal run coming to the holder from the station meter. A plunger, or wooden cylinder about eighteen inches to two feet long and a little smaller in diameter than the pipe, fastened to a pipe handle, the axis of the pipe and the cylinder coinciding, is then inserted and worked up and down so as to impart a surging motion to the whole body of water. The surging back and forth of the water dislodges the naphthalene that is not dissolved and the large pieces rising to the surface are fished out, the remaining fine particles being pumped out with the water. It is rather a difficult matter to get the large body of water contained in pipes above 16 in. in diameter moving with sufficient velocity to dislodge the compact masses of naphthalene, but if the motion can be produced, "plunging" is a very effective method for the removal of naphthalene from the pipes.

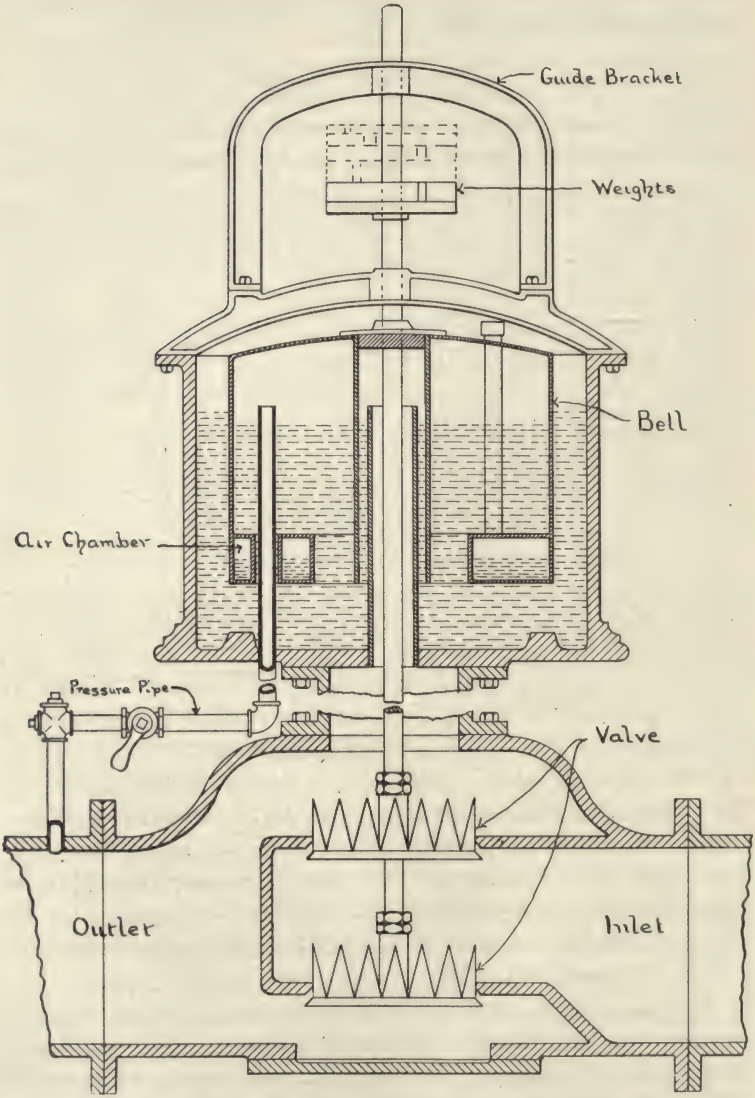
When naphtha or any other liquid solvent is used it is not economical to pour it into the pipe by itself, since, if this is done, it will cut channels in the deposit through which it will run to the drip before it is fully saturated with naphthalene. A better effect can be obtained by pouring water into the inlet until it is filled to half its height. Then from four to five gallons of solvent naphtha are poured in, and the water slowly pumped out of the drip, so that the liquid gradually falls in the main. The consequence is that the solvent, which forms a layer on the top of the water, is forced to act on the whole of the interior surface of the main, both where the latter is upright and where it is nearly horizontal. The time during which it acts on the surface is determined by the rate of pumping, and thus may be made sufficiently long to complete the solution of the naphthalene. When the solvent has reached the elbow, the rate of pumping is diminished in order to give it time to act on the greater horizontal section of the pipe which then becomes exposed to it. By this method of treatment the whole of the inner surface of the pipe is freed from naphthalene, which is completely removed from the main through the pump.

Street Main Governors.

184. Give a description, illustrated by sketches, of a simple, non-automatic street main governor and explain its action.

Ans. As usually made, simple non-automatic street main governors consist essentially of a cast iron valve box, inserted in the main leading from the outlet of the holders to the street mains and containing a double, balanced valve; a cast iron water tank placed vertically over the valve box, but not necessarily directly upon it; a bell made of sheet iron and similar to a small gas holder working in the tank, this bell being fastened to the valve rod so that as it rises or falls the valve moves with it; and a small gas pipe connecting the outlet from the valve box with the interior of the bell, which is thus always supplied with gas under outlet pressure. The form of these various parts and the manner in which they are combined vary in different styles of governors. Thus the valve may be conical, parabolic or cylindrical. When the latter form is used the side of the cylinder is pierced with V shaped openings placed with the points down. Whatever its shape it should be made so that the upward and downward pressures exerted upon it by the gas will be equal and so neutralize each other. The bell is made sometimes with an air chamber large enough to support by its buoyancy the combined weight of the valve, rod and bell, and sometimes without such an air chamber. In the latter case the weight of the bell, valve and rod is counterbalanced by removable iron weights carried on rods suitably attached to either levers or chains fastened to the bell.

In the governor illustrated on the cut the valve is made cylindrical and is balanced by being made double and being set so that the pressure of the gas on both the inlet and outlet sides of the governor is exerted upward on one valve and downward on the other. The bell is provided with an air chamber of such size that, when the bell is in place in the tank and fastened to the valve rod and the tank is filled with water,



NON-AUTOMATIC STREET MAIN GOVERNOR.

the buoyancy of the bell will be sufficient to raise the valve and keep it pressed tightly against its seats. The valve rod after being fastened to the top of the bell is continued above it through a hole in a bracket bolted to the top of the tank, and is thus guided at the top. The same style of governor is made without this guide for the valve rod at the top, but in that case the bell must be guided by means of rollers fastened to the bottom and running in grooves in the sides of the water tank. Gas from the outlet side of the governor is brought under the bell by means of the small pipe shown on the cut, which is connected into the main on the outlet of the governor and passes up through the bottom of the water tank to a point above the water line inside of the bell. This pipe is provided with a stop cock. Between the valve box and the water tank is inserted a piece of flanged pipe, the length of which is made to suit local conditions, it being customary to have the valve placed in the basement or cellar under the governor room, while the tank and bell are on the ground floor.

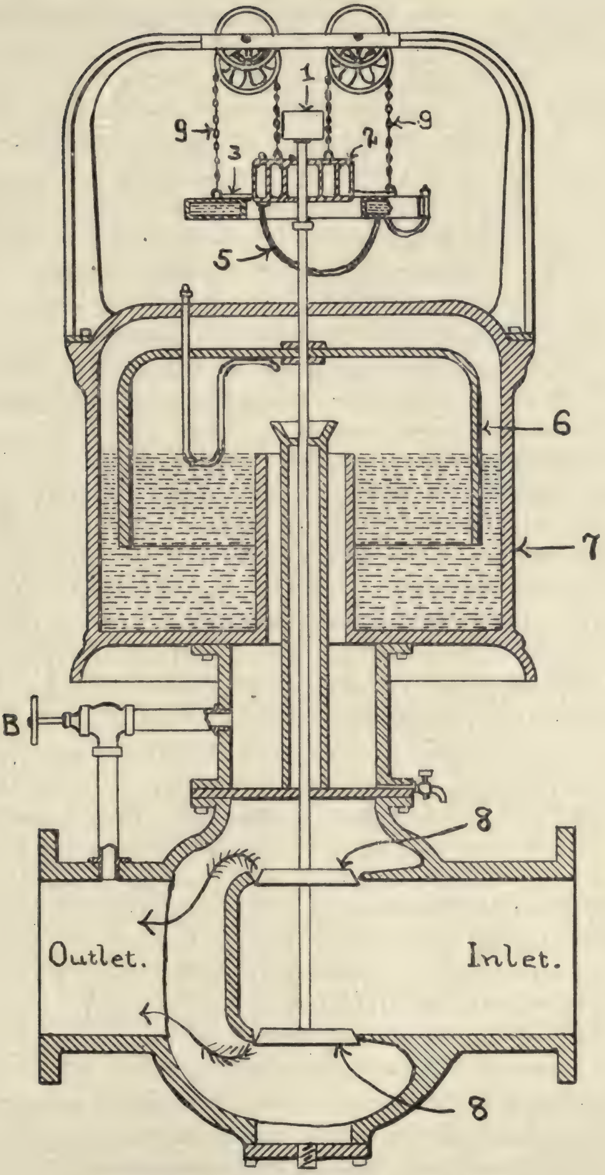
When the governor is to be put into action, water is run into the air chamber at the bottom of the bell, through the pipe shown on the cut as connected into the air chamber and brought up through the top of the bell, until the weight so added is sufficient to prevent the bell from being in equilibrium unless the pressure inside of it is equal to the minimum pressure that it is desired to carry at the outlet of the governor. The effect of the addition of this weight to the bell is to cause it to fall and so open the valve until the opening is large enough to permit gas to pass through in sufficient volume to maintain this minimum pressure on the outlet side of the valve and therefore under the bell. When it is desired to carry a higher pressure on the outlet the bell is loaded with one or more iron weights, placed on a shelf fastened to the continuation of the valve rod above the top of the bell. This extra load increases the pressure required to keep the bell in equilibrium and so causes it to again fall until the valve opening is increased sufficiently to supply gas rapidly enough to maintain on the outlet, and consequently under the bell, the higher pressure for which the governor is set. Any pressure for which it is thus set will be maintained at its outlet in spite of any variations that may occur in the demand for gas. If the demand increases, the first effect is to cause the outlet pressure to fall slightly, and this fall being transmitted to the gas under the bell, the pressure there will no longer be sufficient to maintain the equilibrium. The bell will therefore fall and the valve open until the pressure is brought back to the proper point. If the demand decreases the first effect is to increase the outlet pressure and therefore the pressure under the bell. By this increase it is again thrown out of equilibrium and caused to rise, owing to the pressure being greater than is required to balance the weight with which it is loaded, and this rising of the bell closes the valve and thus reduces the pressure to the proper point.

When a change in the pressure is desired, the amount of weight on the governor must be varied to suit, being increased to produce a higher pressure and decreased to give a lower pressure.

185. Give a description, illustrated with sketches, of some form of street main governor which is automatic in its action—that is, increases the pressure at its outlet as the demand for gas increases and decreases the pressure as the demand for gas falls off, and explain its action.

Ans. An automatic gas governor is one that will automatically establish and maintain predetermined pressures. The old style of balanced governor is capable of changing the volume of gas sent out while maintaining a uniform pressure at its outlet. Any desired change in the pressure, with this style of governor, is effected by adding or removing weights by hand. A perfect and automatic governor, for use in maintaining the supply of gas to a system of street mains, must change volume and pressure together, without manipulation, the pressure being maintained always somewhat in proportion to the volume of gas going out.

One form of automatic governor in successful operation is shown in the accompanying cut. It consists of a bell, 6, floating in a tank, 7, its interior being supplied with gas through a



AUTOMATIC STREET MAIN GOVERNOR.

pipe and valve B, connected with the outlet of the governor, and subject to the pressure on the street mains at the governor outlet. When the bell is floating with a certain pressure in the street mains, it can be readily seen that as long as this pressure is furnished there will be no tendency on the part of the bell 6 to change its position; but if through an increased consumption on the main, the pressure in the main is reduced, the pressure in the pipe B and under the bell 6 will be reduced, and the bell will tend to fall, giving more opening to the valves, 8, in the valve chamber of the governor, and permitting more gas to pass. So far, the action of the automatic governor is like that of an ordinary governor. The automatic governor differs from the ordinary governor in that with this change in the position of the bell comes a change in the position of the weight balancing the gas pressure under the bell. This change is made by an ingenious contrivance, as shown in the cut. 3 is an annular ring containing mercury, and connected by means of the rubber tube 5 with another annular ring 2 which also contains mercury. But the ring 2 is rigidly attached to the valve-rod connected with the valves 8, and any increase in the weight of 2 tends to depress the bell and the valve-rod, giving more opening to the valve; whereas 3 is connected to the valve-rod by means of a chain or wire 9, passing over pulleys. Any increase in the weight of 3, therefore, tends to raise the valve-rod, the bell and the valves. If, now, there be a transfer of mercury through the tube 5, from the annular ring 2 to the annular ring 3, the annular ring 3 will tend to fall, raising the annular ring 2, and the valve-rod, bell and valve. If, on the contrary, there be a transfer of mercury from the annular ring 3 to the annular ring 2, there will be an addition of weight to the valve-rod, and it and the bell and the valves will tend to fall and the valves to open. The level of the mercury in 2 and 3 will remain always the same—this for the reason that 2 and 3 are connected by a rubber tube. When, then, the pressure has fallen in the street mains, and, therefore, under the bell, and the bell sinks, giving more opening to the valves 8, the ring 2 descends with the bell, the ring 3 is raised, because the wire or chain 9, passing over the pulleys, must follow the action of the ring 2, raising the ring 3 and causing some of the mercury to flow from it into the ring 2. We have, therefore, due to the reduction of pressure in the street mains, an increased opening on the valve, and an increase in the weight tending to hold the valve open, which means an increase of pressure. If, now, from the reduction in the consumption of the gas, the original pressure in the street mains is restored, there will be an increase in pressure under the bell 6, which will give it a tendency to rise. It will carry with it the ring 2, depressing the ring 3, and there will be a flow of mercury from the ring 2 into the ring 3. At the same time the valve will partly close and there will be a restoration of the conditions existing before the governor came into action.

The cup 1 is intended to receive weights used in adjusting the governor to the conditions under which it is to operate. These conditions once being established, and the governor being arranged to meet them, it requires no further attention, except to keep it clean and oiled. This governor can be so set that it will, for any given fall of pressure in the street mains, give a predetermined opening of the valves 8, and a predetermined pressure at the outlet of the governor, all within the limits permitted by the pressures thrown by the holders.

A feature of this governor is the provision made for its adjustment to meet the different conditions existing in works of the same size.

To illustrate this: We will take two works, each sending out 150,000 cu. ft. per day, the holder pressure being $\frac{30}{10}$, and the maximum send-out being 25,000 cu. ft. per hour. For one of the works, say at "Gastown," the condition of the mains is such that a maximum pressure of only $\frac{20}{10}$ is required, and a day pressure of $\frac{10}{10}$ is sufficient.

For the other works, say at "Lightville," the condition of the mains and services is such that a day pressure of $\frac{18}{10}$ and a maximum pressure of $\frac{28}{10}$ is required; the margin of difference between holder and maximum pressure in this case being only $\frac{2}{10}$ against a difference at the other works of $\frac{10}{10}$. In each case the same volume of gas passes through the governor valve in the same space of time. In the case of "Gastown" the valve would be open about 1 inch, and of "Lightville" 3 inches, or more.

To adapt the governor to meet such variable requirements and conditions, a series of three compartments or concentric vessels, 2, are arranged around and attached to the valve stem, each of a different capacity and so arranged that by adjusting to use any one, or any two, or all three at once, a given quantity of mercury can be made to form a column of mercury of any one of seven different heights. This enables the superintendent to secure a transfer of any desired quantity of mercury on any stroke of the valve.

The volume of mercury transferred for any given movement of the valve, valve stem and vessel 2 is increased by increasing the area of vessel 2. This vessel is so arranged that it may have any one of seven areas, as desired. The area to be used depends upon the conditions under which the governor must work.

In setting or adjusting the governor to meet the requirements of a works, the superintendent determines what pressure he desires at the lowest point of the district. He may desire to maintain at this point, say 1-inch pressure. He may find that to do this a day pressure of $\frac{15}{10}$, and a night pressure of $\frac{25}{10}$ must be maintained at the works; a difference of $\frac{10}{10}$. Six ounces of mercury for each tenth (or 60 ounces) are put into ring 3. The governor is then weighted (in cup 1) to carry the day pressure of $\frac{15}{10}$. When the consumption increases, the valves at once open, as above; this lowers vessel 2 and the mercury flows from 3 into 2, the result being to increase the weight on one side and diminish it on the other. Say the valve has opened in response to demand enough to transfer 6 ounces; this would equal placing 12 ounces on the valve stem, and the bell or float having this extra weight, the pressure is increased correspondingly. When the maximum volume is reached, all of the mercury is in vessel 2, and the full pressure of $\frac{25}{10}$ is on.

Miscellaneous.

186. How should a gas works be situated with reference to the level of the district to be supplied?

Ans. "It may be taken as a rule that, other things being equal, the works should be situated below * * * * * the general level of the district supplied, as by that means advantage can be taken of the natural increase in the pressure of the gas as it travels from the lower to the more elevated parts." (King's Treatise.)

187. What does a gas man mean when he uses the term "back pressure?"

Ans. "By 'back pressure' is generally meant the total resistance offered to the passage of the gas from any point in the apparatus to its destination in the holder. For instance, the back pressure at the inlet of the purifiers would consist of the resistance of the purifiers plus the resistance of the station meter, plus the holder pressure, plus the friction in the pipes and connections. The term is also used to designate the resistance offered by any particular part of the apparatus. For instance, the difference in the pressure at the inlet and outlet of the purifiers would be spoken of as the 'back pressure thrown by the purifiers.'"

188. Explain the construction and use of the syphon pressure gauge.

Ans. "The syphon pressure gauge consists of a U-shaped glass tube, or of two vertical glass tubes cemented into a connecting tube at the bottom, and containing water to a point about midway of the height. When the water in each of the vertical tubes is exposed to atmospheric pressure the height of the water in each tube will be the same. In gas manufacture the syphon gauge is used to determine the difference between the pressure of the atmosphere and the pressure of the gas in any part of the apparatus or connecting pipes to which it may be attached. Connection is made between the apparatus, or pipe, and the top of one of the vertical tubes of the gauge. If the pressure in the apparatus is greater than that of the atmosphere, the water in the tube connected with the apparatus will be depressed—the water in the other rising until the difference in the heights represents the difference between the pressure in the apparatus and the pressure of the atmosphere. If the pressure in the apparatus is less than that of the atmosphere, the water will rise in the tube connected as above to the apparatus, being depressed in the tube open to the atmosphere, until the difference in the heights of the two columns of water represents the difference between the pressure in the apparatus and the pressure of the atmosphere. This difference is commonly expressed in inches and tenths of an inch."

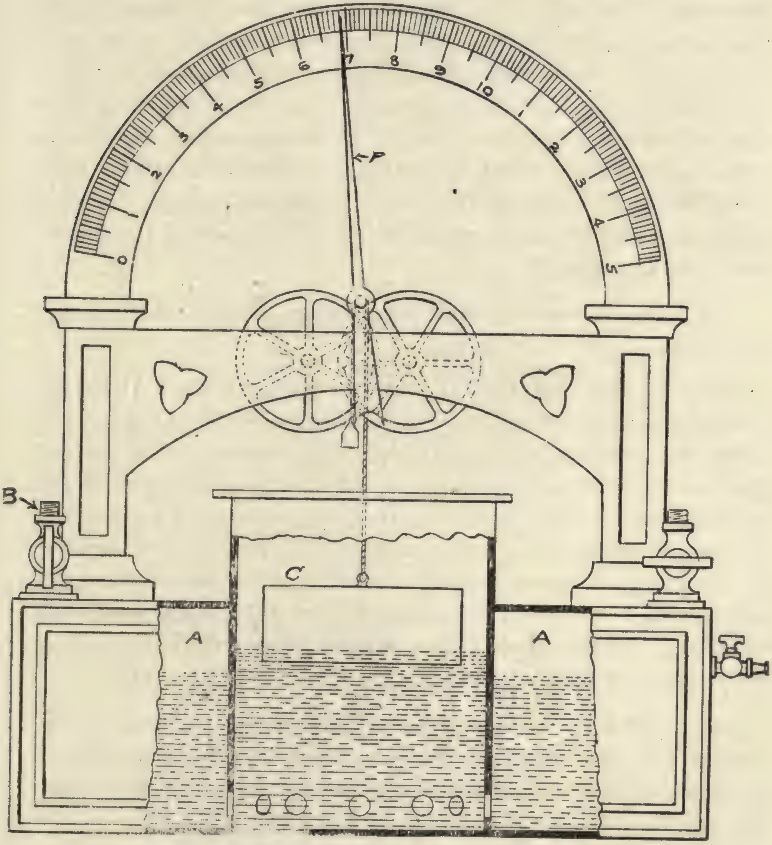
189. What does the ordinary U or syphon pressure gauge indicate, and what is the object of its use in gas works?

Ans. The ordinary U or syphon pressure gauge shows the difference between the respective pressures acting on the surface of the liquid in each leg of the gauge. As used in a gas works it indicates the difference between the atmospheric pressure acting on the water in the leg open to the air, and the pressure of the gas acting on the water in the leg in communication with the interior of the pipe, or piece of apparatus, to which it is attached. Therefore, the pressure shown by the U gauge to be existing in any piece of apparatus is not absolute pressure, but merely the difference between the pressure in the apparatus and that of the outside air. This difference in pressure is expressed in terms of the height of the column of water that it will support. When the difference is positive, that is, when the pressure in the apparatus is greater than that of the air, it is called a "pressure." When the difference is negative, that is, when the pressure in the apparatus is less than that of the air, it is called a "vacuum."

The main object of the use of pressure gauges in gas works is to furnish, at any and all times, information as to the amount of obstruction to the passage of the gas existing in each piece of apparatus as well as to the total amount offered by all of them combined. A proper distribution of pressure gauges among the various pieces of apparatus enables the operator to promptly detect and quickly locate any tendency to blocking up that might lead to serious trouble if it were not detected and corrected.

190. Give a description, illustrated by sketches, of a "King's" pressure gauge.

Ans. A "King's" pressure gauge consists of a hollow box divided into concentric compartments, of which the larger, A, into which the gas is admitted through the inlet B, is closed to the atmosphere, and the smaller, C, is open to the air at the top and is in communication with A at the bottom. When



KING'S PRESSURE GAUGE.

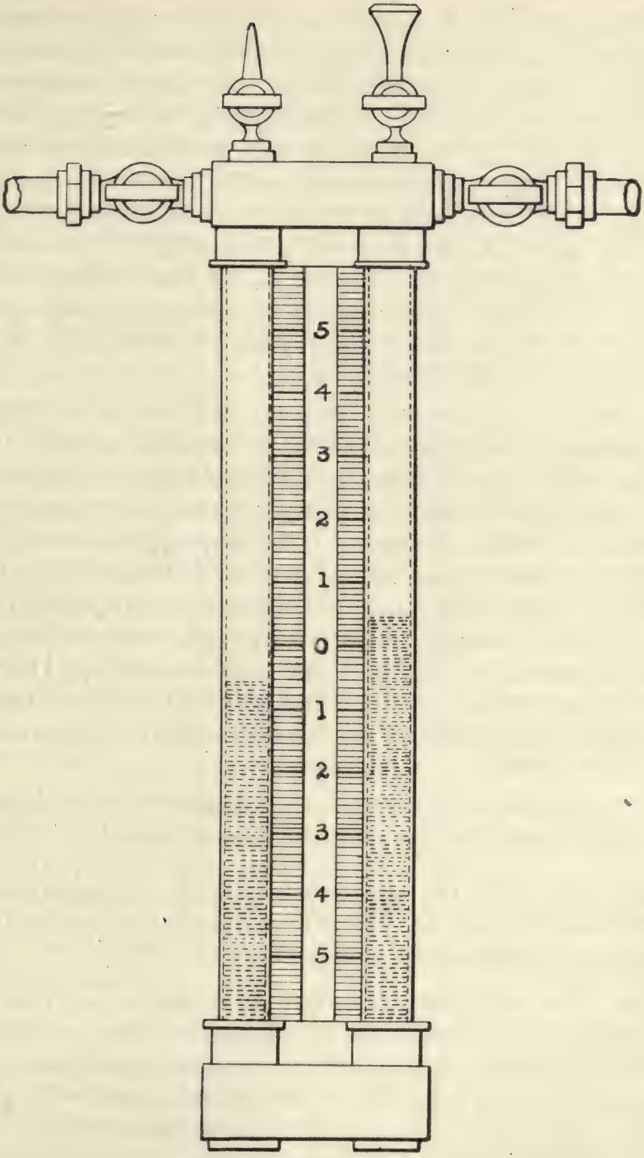
both chambers are filled with water to a determined level and gas is admitted to A, the water in A is depressed and rises in C until the difference in levels is equal to the pressure of the gas on top of the water in A. A small metal float rises and falls with the surface of the water in C, and its motion is communicated by a cord and pulley wheel to the pointer P. This pointer moves through an arc of a circle and indicates the pressure on a graduated semi-circular scale. The travel of the pointer for any given motion of the float depends on the size of the pulley wheel. The proportions of the apparatus, and therefore the travel of the pointer over the scale for any given rise of water in the chamber C, may be arranged to give the instrument almost any degree of sensitiveness ; that is, to indicate small variations in pressure, smaller variations than could be easily read on the ordinary syphon gauge. King's pressure gauge is the invention of Mr. King, late of the Liverpool Gas Company.

191. Describe a "differential pressure gauge," and explain its action.

Ans. "The differential pressure gauge differs from the ordinary syphon gauge only in its mode of attachment. The latter has one end open to the air, and serves to indicate the difference between the pressure of the gas and that of the atmosphere ; while the differential gauge shows the difference in the gas pressures at two points. For instance, if one arm of the gauge is connected with the station mêter inlet and the other with the outlet, the difference in the water levels will represent the difference in pressure at these points, or the loss of pressure in passing through the meter." (See cut.)

192. What is indicated by an abnormal increase in the pressure at the outlet of the exhauster, and how would you proceed to determine the exact point at which the cause producing this increase in pressure is located ?

Ans. An abnormal increase in the pressure at the outlet of the exhauster in a gas works indicates a partial blocking up of the gas way at some point in the pipes and apparatus lying between the exhauster and the holder. When any such



DIFFERENTIAL PRESSURE GAUGE.

increase of pressure is observed, the location of the obstruction should be determined at once in order that measures may be taken to ensure its removal before it becomes great enough to interfere seriously with the operation of the works. If the plant is provided with pressure gauges on the inlet and outlet of each piece of apparatus, any obstruction of the gas way can be readily located by an inspection of these gauges, since the first gauge beyond the obstruction will show a normal pressure, and therefore it is certain that the trouble will be found in the piece of pipe or apparatus where the gauge at the inlet end shows an abnormal pressure and the gauge at the outlet end shows a normal pressure.

If there is not a pressure gauge at each end of each piece of apparatus, the obstruction may perhaps be located by by-passing each piece in turn, noting the change in pressure in each case, until the piece of apparatus throwing the abnormal pressure is found. However, if the stoppage is in the pipes between the outlet of one by-pass and the inlet of the next this method will not locate it, and in the absence of gauges fixed as above it will be necessary to attach a gauge at each end of each piece of apparatus and note the pressures existing, taking them in succession one after another, until the two consecutive points between which the abnormal difference in pressure occurs are found.

When this has been done the piece of pipe or apparatus that is at fault should be cleaned out as soon as possible.

193. What are the precautions that should be taken in laying fire bricks and fire clay blocks to secure for the finished work strength and ability to resist heat?

Ans. The principal precautions to be taken in laying up fire bricks or fire clay blocks are that the bricks, or blocks, should be well wetted just before they are laid in place, and that each brick, or block, should be rubbed into place in such a way as to bring its faces almost into contact with the faces of the adjacent bricks, or blocks, in the wall, the joints being made as thin as it is possible to have them and at the same time have the fire clay fill all the interstices so as to give a uniform bearing over the whole surface. This is especially important in the case of arches, which should be laid as nearly as possible with the blocks face to face. Bricks and small blocks can be wet by dipping them into water in a bucket, kept filled and at hand for the purpose, each piece being dipped by the mason as he picks it up for the purpose of laying it in place in the wall. The surfaces of large blocks should be wet by having water sprinkled on them, a convenient method being to employ for the sprinkling a whisk broom which is wet by being dipped into the water in the bucket. The portion of the work previously laid, upon which the bricks, or blocks, are to be placed, should also be wet in the same way.

To secure thinness of joints, those surfaces of the blocks which come together should be smooth plane surfaces, being dressed to this condition if they do not originally possess it, and the fire clay must be mixed thin rather than stiff, care being taken not to get it so thin that it will run out of the joint, nor so stiff that any excess will not be squeezed out when the block is worked into place. If the joints are not made thin the fire clay will soften and run out of them when the work is subjected to heat, or even if it does not do this it will shrink under the action of the heat and cause a settlement of the upper part of the brick work.

Another precaution which should be observed is that when it is necessary to cut bricks, or blocks, the cut surfaces should never be exposed to the direct heat of the fire, the face so exposed being always one which has not been cut.

194. What tests would you apply to a fire brick to determine its quality?

Ans. The qualities desired in a fire brick are, infusibility, strength, regularity of shape, uniformity of composition and facility of cutting, and the tests to be applied to a fire brick should be such as will determine to what extent it possesses these qualities.

The degree of infusibility can be determined, to a certain extent, by an analysis of the material of which the brick is composed. If this analysis shows the presence of about 60% of silica, less than 6% of sesqui-oxide of iron and not more than 2% to 3% as a total of lime, magnesia and the hydrates of potassium and sodium, the brick probably possesses a high degree of infusibility. If the analysis shows more than 6% of sesqui-oxide of iron or 2% to 3% of the lime, magnesia, etc., the brick should be rejected. But exposure of the brick to the action of heat under the conditions to which it will be subjected when used furnishes the best test for infusibility. In coal gas works the test can be made by placing the brick in the combustion chamber of a recuperative bench. If, when the brick is removed after being exposed for a week or ten days to the heat of the combustion chamber, the edges and the corners are found to be sharp, and the surfaces show no signs of incipient fusion, the brick may be passed as of first rate quality as far as infusibility is concerned. In water gas plants the space at the bottom of the superheater, in which the secondary combustion occurs, furnishes a good place for a test.

If the material of which the brick is made is well compressed during manufacture and the brick is hard burned, there is no question as to its strength when cold. The degree to which compression has been carried is indicated by the weight of the brick, and a fire brick of the regulation size, 9 in. × 4½ in. × 2⅝ in., should weigh from 7¼ to 7½ lb. A well burnt brick usually shows a reddish tinge. A well compressed and well burnt brick will give a ringing sound when struck with a hammer. It is especially important that the bricks which are to be used for lining the furnaces of retort benches, or for lining water gas generators, should be hard, since they are subjected to a great deal of abrasion from the fuel and the clinkering bars, so that for this work hardness and strength are of more importance than infusibility. In the combustion chamber, on the contrary, infusibility is the most important quality, since the material used there is not exposed to any wear and tear except that arising from the effect of the heat. It may thus frequently happen that the same brick is not suitable for use both in the furnace and in the combustion chamber.

An examination of the exterior of the brick is all that is necessary to determine whether or not it possesses regularity of shape.

Uniformity of composition can be tested by breaking the brick and examining the surface of the fracture. This should present a compact and uniform appearance, though not necessarily a close and fine texture. In fact, some authorities consider a coarse texture to be preferable. Uniformity of composition is also indicated by the giving out of a clear ringing sound when the brick is struck a sharp blow with a hammer.

Facility of cutting is important only as reducing the cost of labor and the amount of waste during the operation of laying the brick, and while desirable, if it can be secured without sacrificing the more important qualities, it cannot be considered an equivalent for any one of them.

195. What is a paint? What is a varnish?

Ans. Technically, a paint is a mechanical mixture of a liquid (generally linseed oil, with turpentine known as the "vehicle") and a finely divided solid (as white lead or red oxide of iron, known as the pigment, or coloring substance), sufficiently fluid to be applicable to surfaces with a brush, and having the property of drying upon surfaces coated with it to a hard, continuous, tenacious and somewhat elastic skin, protecting them from air and moisture, and giving them the color of the pigment used.

Paint acts, therefore, as a preservative and a decorative covering.

The pigment in its dry state is also called "paint."

An oil, or mixture of oils, to be valuable in a paint, should have the property of drying when applied to a surface, to a hard, lustrous and tenacious skin.

Water is sometimes used as the vehicle of a paint. A simple mixture of water and a pigment does not adhere to surfaces with the tenacity of oil paints.

A varnish is a solution of a resinous substance (as amber, copal, shellac, etc.) in an oil or spirit (as linseed oil, turpentine, alcohol, or methylated spirit), which will dry and harden, and remain transparent. When the solvent is an oil, the varnish is known as an "oil varnish." When the solvent is a spirit, the varnish is known as a "spirit varnish." Varnishes, when applied to wood, metal, or other surfaces, dry and form a hard, smooth, transparent, and somewhat elastic surface, protecting the material covered from the air and moisture. Varnishes may be colored by the addition of substances that give color without making the mixture opaque.

Photometry.

196. What is the unit used in Great Britain and America for measuring and expressing the illuminating value of gas, and what is the value of this unit?

Ans. The unit used in Great Britain and America for measuring and expressing the illuminating value of gas is the "candle power." The literal meaning of "candle power," as a measure of illuminating value, is the amount of light given by the flame of a candle. It is, however, evident that the flames of different candles give different amounts of light, and therefore, to obtain an amount of light that shall be as nearly as possible a definite and unvarying quantity and fit to be used as a unit of measurement, it is necessary that the candles employed should be made and burned in accordance with certain rules. Candles so made and used are called standard candles.

It is also evident that after having obtained a standard candle, before any deductions can be made as to the comparative candle powers of different gases as obtained by separate observations, it is necessary that the rates at which, and the burners in which, the gas is consumed must be uniform, since the same gas consumed at different rates in one burner, or at the same rate in different burners, will give different amounts of light. Therefore, the term "candle power" implies the use of a standard candle burning at a definite rate and of a standard burner and rate of consumption for the gas.

The standard candle is a sperm candle of six to the pound and is burnt at a rate of 120 grains of sperm per hour. For a long time these general requirements were the only ones that had to be met, but wide variations in the amount of light given by different candles, all of which fulfilled the above requirements, led the London Gas Referees to adopt regulations for securing uniformity in standard candles, which prescribe the method and materials to be used in the manufacture of the wicks and the melting point of the spermaceti that are to be employed in making such candles. In the absence of any regulations on the subject in this country, it is well to see that the candles used fulfill as nearly as possible the requirements of the Gas Referees. These requirements are given in full in the answer to question No. 197.

The standard rate of consumption for the gas is 5 cu. ft. per hour. The form of burner used as the standard varies with the locality and the nature and the quality of the gas to be tested. In England, for the testing of coal gas of from 14 to 16 candle power, the burner originally prescribed by law for use as the standard burner was a special form of Argand burner known as Sugg's London Argand No. 1. In 1906 a new standard burner known as the Metropolitan Argand No. 2, or the Carpenter burner, was adopted as the standard for London and is being rapidly adopted all over Great Britain. For cannel gas of from 20 to 26 candle power a flat flame burner is commonly prescribed as the standard. In this country the No. 7 Bray Slit Union burner has been very generally adopted as the standard burner, especially where the gas to be tested is either a carburetted water gas or a mixture of this gas with coal gas. The London Argand is also used in many instances for coal gas. The New York Commission of Gas and Electricity has recently made regulations for the testing of gas in New York State, which provide that the tests of illuminating power shall be made with either a new style F Argand burner, old style D Argand burner or No. 7 Slit Union Bray burner, as may be best suited to the gas tested. It is always necessary to note what burner has been employed as a standard in each case before any comparison can be made between the reported candle powers of the gases supplied in different localities.

From what precedes it is seen that when it is said that a gas is of a certain candle power the idea intended to be conveyed is that the gas will, when burned in a standard burner at the rate of 5 cu. ft. per hour, produce a flame which gives a light equal to that given by a certain number of standard candles, each consuming 120 grains of sperm per hour.

197. What is the meaning of "candle power" in the statement "this is a 20 candle power gas?"

Ans. The words "candle power" in the statement "this is a 20 candle power gas" are used to denote the amount of light given by the flame produced when any gas is burned in a standard burner at the rate of five cubic feet per hour, expressed in terms of a unit, which is the amount of light given by a standard sperm candle of six to the pound burning at the rate of 120 grains per hour. The statement "this is a 20 candle power gas" is, therefore, a statement that the gas named will, when burned in the standard burner at the rate of five cubic feet per hour, produce a flame giving an amount of light twenty times as great as that given by a standard sperm candle of six to the pound burning at the rate of 120 grains per hour.

Different forms of burners are used in different localities as the standards for the purpose of determining the candle power of gas. In England, when the gas to be tested is a coal gas of from 14 to 16 candle power, the burner formerly generally prescribed by law for use as the standard burner is a special form of Argand burner known as Sugg's London Argand, No. 1. Since 1906 another form of Argand burner, known as the Metropolitan No. 2 or Carpenter burner, has been largely adopted as the standard burner to be used in determining the illuminating value of gas of the quality named above. For cannel gas of from 20 to 26 candle power a flat flame burner is commonly prescribed as the standard. In the United States the No. 7 Bray Slit Union burner has been very generally adopted as the standard burner, especially where the gas to be tested is either a carburetted water gas or a mixture of this gas with coal gas. The London Argand is also used in many instances for coal gas, being specified by the Gas Commissions of Massachusetts and the Second District of the State of New York. It is always necessary to note what burner has been employed as a standard in each case before any comparison can be made between the reported candle powers of the gases supplied in different localities.

As far as the candles are concerned the only qualifications generally adopted are that they shall be sperm candles of six to the pound and shall be burnt at the rate of 120 grains per hour. Wide variations in the amount of light given by different candles, all of which fulfilled the above requirements, led the London Gas Referees to adopt regulations for securing uniformity in standard candles which prescribe the method and materials to be used in the manufacture of the wicks and the melting point of the spermaceti that are to be employed in making such candles. In the absence of any regulations on the subject in this country it is well to see that the candles used fulfill as nearly as possible the requirements of the Gas Referees.

These requirements, as given in Butterfield's Chemistry of Gas Manufacture, are as follows :

"Regulations for Securing Uniformity in Standard Candles.—1. The wicks shall be made of 3 strands of cotton plaited together, each strand consisting of 18 threads. The strands shall be plaited with such closeness that when the wick is laid upon a rule and extended by a pull of about 1 ounce, just sufficient to straighten it, the number of plaits in 4 inches shall not exceed 34 nor fall short of 32.

"Each wick shall be of suitable length, not less than 12 inches, and looped ready for fixing in the mould. After having been bleached in the usual manner and thoroughly washed, the wicks shall be steeped in a liquid made by dissolving 1 ounce of sal-ammoniac and 1½ ounces of crystallized boracic acid in a gallon of distilled water; they are then to be gently wrung or pressed till most of the liquid has been removed, and dried at a moderate heat while lying horizontally.

"Such a wick cut to a length of 12 inches, when stretched as above, shall weigh not more than 7 nor less than 6 grains. The weight of the ash remaining after the burning of 10 wicks which have not been steeped in boracic acid, or from which the boracic acid has been washed out, shall be not more than 0.03 grain.

"Wicks made in accordance with this prescription shall be sent to the office of the Gas Referees, by whom they will be examined and certified.

"The wicks so certified are to be used by the candle-maker in the condition in which they are returned to him.

"When the wicks are set in the mould, they should be pulled with only so much force as is necessary to straighten them.

"2. The spermaceti of which the candles are made shall be genuine spermaceti, extracted in the United Kingdom from crude sperm oil, the product of the sperm whale (Physeter macrocephalus). It shall be so refined as to have a melting point lying between 112° and 115° F. An account of the method by which the melting point of the spermaceti is to be determined is given later.

"Since candles made with spermaceti alone are brittle, and the cup which they form in burning has an uneven edge, it is necessary to add a small proportion of beeswax or paraffin to remedy these defects. The best air-bleached beeswax, melting at or about 144° F., and no other material, shall be used for this purpose, and the proportion of beeswax to spermaceti shall be not less than 3 per cent. nor more than $4\frac{1}{2}$ per cent.

"3. The candles made with the materials above prescribed shall each weigh, as nearly as may be, $\frac{1}{6}$ of a pound, and will be found to answer to the following test: Immerse a candle taper-end downwards in water of 60° F., with a brass weight of 40 grains attached to the wick by a small piece of thread; when a further weight of 2 grains is laid on the butt end of the candle it will still float, but with a weight of 4 grains it will sink.

"The candles shall be sent to the office of the Gas Referees, by whom samples from each batch will be examined and tested. Each batch of candles shall be accompanied by a specimen of the spermaceti (unmixed with beeswax) which was used in making them.

"Method of Washing Wicks.—As it is found to conduce to the regular burning of candles that the wicks should have been as far as possible cleaned and freed from mineral matters, it is recommended that the candle-maker, before steeping the wicks, shall wash them first in distilled water made alkaline with between 1 and 2 per cent. of strong liquid ammonia, then soak them for several hours in dilute nitric acid containing about 10 per cent. of strong acid, and finally wash them in distilled water made alkaline with a few drops of ammonia.

"Method of Determining the Melting Point of the Spermaceti.—As various methods are used by different refiners of spermaceti for determining the melting point, which lead to different results, it must be noted that the temperatures here given as the limits within which the melting point of a sample of refined spermaceti should fall—viz., 112° and 115° F.—have been found by the following method, which is known as the capillary-tube method:

"A small portion of the spermaceti is placed in a short test-tube, and melted by plunging the lower end of the tube in hot water. A glass tube drawn out at one end into a capillary tube about 1 mm. in diameter is dipped narrow end downwards into the liquid spermaceti, so that, when the tube is withdrawn, 2 or 3 mm. of its length are filled with spermaceti, which immediately solidifies. The corresponding part of the exterior of the tube also becomes coated with spermaceti, which must be removed.

"The narrow part of the tube is then immersed in a large vessel of water at a temperature not exceeding 110° F. The lower end of the tube, which contains the spermaceti, should be 3 or 4 inches below the surface, and close to the bulb of a thermometer. The upper end of the tube must be above the surface, and the interior of the tube must contain no water. The water is then slowly heated, being at the same time briskly stirred, so that the temperature of the whole mass is as uniform as possible. When the plug of spermaceti in the tube melts, it will be forced up the tube by the pressure of the water. The temperature at the moment when this movement is observed is the melting point."

198. Describe the way in which standard candles should be used and handled, when making a photometric test, to make them yield the proper amount of light when burning at the specified rate of 120 grains per hour.

Ans. When candles are used as the standard of light in making a photometric test, the first precaution to be taken is to be certain that the candles are standard candles It is necessary to depend for this upon the reputation of the manufacturer by whom the candles are made. The long candles, that is, those from 8¼ in. to 9 in. long measured from the shoulder, give, as a rule, more consistent results than do the short ones.

All modern candle balances are made to take two candles at a time, as the use of two flames instead of one throws the position of equal illumination of the two faces of the disc nearer the middle of the bar where slight errors in setting make the least difference in the readings, and also neutralizes any variations from the normal in different parts of the candle.

To prepare a candle for use, the conical tip should be cut off even with the shoulder and the end of the candle so left made perfectly square with the axis, so that the candle will stand vertically when placed on its end. It should then be cut in two as nearly as possible at the middle point between the shoulder and the bottom, and then ½ in. of the sperm should be separated from the top of the lower half and the bottom of the upper half. When separating these pieces care must be taken not to injure the wick, and on this account it is advisable to take each off in one piece, by cutting carefully through the sperm at the right distance from the end of the half candle and pulling off from the wick the piece of sperm so separated.

Each of the halves should now be lighted in such a way that the sperm at the base of the wick is melted at the same time that the wick is lighted so that the flow of sperm up the wick will begin at once. This, by preventing the burning away and charring of the wick, reduces the length of time required by the candles before they settle down to their normal condition and rate of burning. When new candles are first lighted it is well to hold them in a horizontal position and revolve them a few times around the wick as an axis, to melt off some of the sperm and burn off any ragged edge that might be left on the wick, but with candles that have been used before, all that is necessary is to melt the sperm at the base of the wick when lighting them.

The candles should be allowed to burn at least twenty minutes after being lighted before the test is made, to render it certain that they have reached their proper condition. The instructions usually given are that they should be lighted at least ten minutes before making a test, so as to allow them to reach the normal rate of burning, but unless they are in the proper condition the light given may vary considerably, even when the consumption of sperm is normal. The attainment of the proper condition can be determined by the appearance of the wick and the top of the candle. "The wick should appear compactly woven and not bent to an exceeding degree out of the upright," and the tip should glow and remain just within the edge of the flame, while the cup at the top of the candle should be well defined and dry. The proper degree of curvature is shown on Fig. 1. Anything beyond this, such as is shown on Fig. 2, is wrong, as is also a perfectly straight

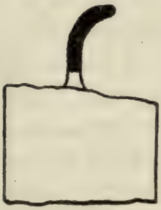


Fig 1.

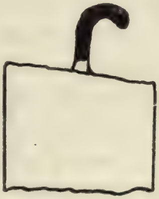


Fig. 2.

wick. When the conditions are as noted above, the flame will be smooth on the edge and of good shape, and the consumption of sperm will always come within the prescribed limits of 114 and 126 grains per hour. If they are not obtained after the candles have been allowed to burn for a sufficient length of time, the candles are at fault and should not be used. Some candles will not get into good condition until they have been burned for a long time, but a candle that has not reached the proper condition at the end of an hour's burning is probably worthless.

When candles are not in use they should be carefully protected from dust, since if they are allowed to become covered with dust this is drawn into the wick as the sperm melts and interferes with the flow of the sperm to the flame, thus interfering with combustion and preventing the candle from giving the proper amount of light.

The position, with reference to the photometer disc and bar, of the planes containing the centre lines of the wicks is also of importance in securing accurate results. The only instructions that are usually given are that the planes of the two wicks should be at right angles to each other, but, as pointed out by Mr. John Methven, these planes can occupy a number of positions with reference to the bar and disc while maintaining the required position relative to each other. The proper position is that in which each wick is at an angle of 45° with the line of the bar, one pointing towards both bar and disc and the other pointing away from both bar and disc, as on Fig. 3.

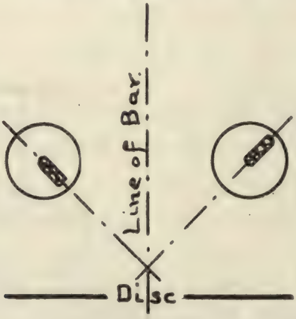


Fig. 3.

It is also necessary that the candles be burned in a well ventilated space free from drafts, and that the time taken for burning forty grains of sperm be accurately determined, but these are questions concerning the design of the photometer room and the accuracy and sensitiveness of the candle balance which need not be discussed in this connection.

Much information as to the causes that affect the amount of light given by standard candles and the proper way in which to handle them to obtain uniform and accurate results is to be found in a paper on Photometry, by Mr. John Methven, American Gas Light Journal, Dec. 9, 1889, and in an article entitled "The Standard of Light," by Walter Grafton, Journal of Gas Lighting, Etc., Vol. LVII, pages 690, 789 and 889.

199. Name and describe one or more of the secondary standards of light that are used in this country to replace candles in determining the candle power of gas.

Ans. The secondary standards of light that are most frequently used in this country to replace candles in determining the candle power of gas are the Edgerton Standard and the ten-candle power Pentane Lamp.

The Edgerton Standard is formed by surrounding the 7 in. × 1¾ in. chimney of a Sugg D Argand burner with a blackened brass sleeve 2 in. in diameter, and thus cutting off from the photometer disc all the light given by the burner flame except that portion which passes through a horizontal slit in the sleeve. This slit is $\frac{13}{32}$ in. high, has its lower edge $\frac{7}{8}$ in. above the top of the steatite ring forming the burner tip, and extends a sufficient distance around the circumference of the sleeve to make it certain that it will give an opportunity for light to reach the disc from the full width of the flame. Directly opposite this slit on the other side of the sleeve another slit of the same size is cut out to prevent any light being reflected from the interior of the sleeve to the disc. A vertical slit running out of the horizontal one just mentioned is also made in the back of the sleeve to form an opening through which the height and appearance of the flame can be observed.

The theory of the standard is that when the burner is kept in good condition and the flame is adjusted to a height of 3 in., a constant amount of light will pass through the slit in spite of variations in the quality of the gas supplied to the burner as long as these variations are not greater than would ordinarily be met with in the supply from any one works. It has been found by experiment that this standard shows the most constant value when the axis of the flame is set $\frac{7}{8}$ in. farther from the middle point of the bar than the normal; that is, when the axis of the flame lies $\frac{7}{8}$ in. behind the plane passing through the plumb lines marking the position of the standard light. The value of the standard is of course not the same when used at different works with entirely different qualities of gas, but once standardized by a series of observations against candles at any works, its value may be assumed to be constant unless extraordinary variations occur in the candle power of the gas supplied. Mr. Rollin Norris, in a paper on "Some Experiments with the Edgerton Standard," read before the American Gas Light Association at the meeting held October 18, 1899, states the following conclusions as the result of a number of tests made with coal gas and carburetted water gas of different qualities:

> "Referring to the Edgerton Standard in its present design, the general conclusions to be drawn from the experiments which I have detailed above are that with water gas the value of the Edgerton is independent, within wide limits, of the candle power of the gas used in it; that with coal gas the value varies with the value of the gas burned, the change being about 10 per cent. of the change in value of the gas used; that with either coal gas or water gas, if the Edgerton be carefully standardized for the condition under which it is to work, it may be relied upon to give results whose error will not exceed $1\frac{1}{2}$ candles, while a large majority of the observations will be correct to within one candle of the value of the gas."

Some experiments reported by Mr. Alten S. Miller for the Research Committee of the Association show that when an Edgerton Standard was not touched after being standardized, the maximum variations under working conditions between its values as determined against candles at different times did not exceed 2.5 per cent., but that it was necessary to restandardize it if it was disturbed in the slightest degree.

While the Edgerton Standard may be open to objection for photometrical work where extreme accuracy is required, it is very valuable for the purpose of making frequent candle power determinations to check the manufacturing operations at a gas works.

The ten-candle power Pentane Lamp in use in this country is a modification of the original Harcourt ten-candle Pentane Lamp, which was designed by Mr. A. Vernon Harcourt and is the standard of light officially adopted by the London Gas Referees for the testing of the gas supplied by the three metropolitan gas companies. The Referees have adopted it as a primary standard of light, but in the United States it is used as a secondary standard.

The modifications in the American lamp consist in the use of a brass tube instead of a rubber tube to carry the mixture of air and pentane vapor from the saturator to the burner, and the insertion in this tube of a small pet cock by means of which the flow of the current of air and vapor can be started if necessary at the time the lamp is lighted, and of a micrometer cock by which the height of the flame can be regulated. All the other parts of the American lamp are the same in design and dimensions as the similar parts of the original Harcourt lamp.

As indicated above, the material burned in this lamp is air saturated with the vapor of pentane, pentane being a distillate produced from petroleum by rectifying gasoline in the manner set forth in the instructions of the London Gas Referees.

The saturator containing the pentane is a square box made of tin plate and is placed upon a bracket fastened to the top of the tube carrying the burner bracket and the chimney and the tube surrounding the chimney. On top of the saturator at each of the two front corners is fastened a stop cock, the one on the left being provided with a funnel and serving both for filling the saturator with pentane and for the air inlet, and the one on the right forming the outlet for the vapor-saturated air. On the inside of the top plate are fastened seven partitions, the lower edges of which do not quite touch the bottom, but are sealed in the pentane as long as this is maintained at the proper height. The partitions are so arranged that, when they are sealed, the air cannot pass directly from the inlet to the outlet, but is forced to travel back and forth across the box eight times, and thus becomes fully saturated with pentane vapor before it reaches the outlet. A glass window is provided in the front of the saturator to enable the operator to see the height at which the pentane stands and thus know when it is necessary to put in a fresh supply.

The brass tube connecting the outlet of the saturator with the burner rises a few inches above the outlet stop cock and then bends over and drops to a point opposite the bottom of the burner, where it makes a right angle turn and runs horizontally to the burner. It is provided with unions at each end to enable it to be easily disconnected, with a pet cock in the bottom outlet of the tee by which the turn to the burner is made, and with a micrometer cock, by which the height of the flame is regulated, on the horizontal run next to the burner.

The burner is an argand burner with a steatite ring having an outer diameter of 0.945 in. and an inner diameter of 0.551 in. and containing thirty holes, each 0.049 in. in diameter. The supply of air to the outside of the flame is regulated by means of a conical hood, which also acts as a screen to hide the flame except on the side toward the disc, and that to the inside is furnished by means of an outer tube around the chimney tube in which an upward current of air is induced by the heat of the chimney. This current passes from the top of this outer tube into a box which carries it across to the inside of the tube to which the saturator and burner brackets are fastened and then descends this tube to the hollow burner bracket through which it passes to the bottom of the burner and thence up inside of the ring to the flame. The burner is placed on the opposite side of the stand from the saturator and with the top of the steatite ring about 15½ in. below the bottom of the saturator.

The brass chimney tube is set, when the lamp is cold, with its lower edge 1.85 in. above the top of the steatite ring. At the bottom of the chimney is a talc or mica window through which the height of the flame can be observed.

The chimney tube is surrounded by an outer tube for the purpose of supplying air to the inside of the flame as described above, the lower edge of this tube being about 2½ in. above the lower edge of the chimney. The bottom of the tube carrying the saturator and burner brackets and the outer tube and air box fits over the end of a rod and rests on a ring clamped to this rod which is mounted on a tripod having a leveling screw at the end of each leg.

When it is to be used the lamp should be placed on the photometer table and adjusted by the leveling screws and the ring on the stand so that the supporting tube is vertical, the top of the steatite burner ring is 0.93 in. lower than the centre of the photometer disc, and the centre of the ring lies in the line formed by the intersection of the plane of the plumb lines marking the position of the standard light and the vertical plane containing the axis of the bar. The chimney must then be accurately centered over the burner and set at the proper height above it. A wooden block 1.85 in. high is provided for setting the chimney at the right height, the adjustment being made by setting the block on the steatite ring and lowering the chimney until it just rests upon the top of the block without binding it.

After the lamp is properly adjusted the saturator is filled about two-thirds full of pentane. As pentane is very inflammable and gives off, even at comparatively low atmospheric temperatures, a vapor which is heavier than air and consequently falls through the air, the saturator must never be filled when the lamp is lighted nor should any other light be brought near it when it is open. When filling the saturator the vapor tube should be disconnected from the outlet stop cock and this stop cock opened to serve as a vent for the air displaced. When the saturator is filled to the proper height the stop cocks should be closed and the tube connected.

The micrometer cock is then closed and both stop cocks on the saturator opened full. (At temperatures of 80° F., or above, the pentane when under atmospheric pressure will give off vapor faster than it is required by the burner and the vapor will issue from the air inlet if this is open. Under these conditions the inlet cock must be kept closed to avoid the danger of having the vapor that would otherwise escape into the air ignite at the burner and cause a fire. The burner is then fed with pentane vapor unmixed with air, but this does not seem to affect the amount of light given by it.) The pet cock at the bottom of the tube is then opened to start the flow of vapor saturated air, the palm of one hand being held below the cock to note by the feeling of coldness produced at the point where the vapor strikes the skin whether a current exists. If the current is not started by the mere opening of the pet cock it can be started by placing the mouth over the opening and sucking. When it is started the pet cock is closed and the micrometer cock opened while a lighted match is held over the burner until the pentane lights. The flame should then be turned up until it nearly enters the chimney and the lamp allowed to heat up, as it will not be possible to make the final adjustment of the height of the flame until it has been burning for from twenty minutes to half an hour. The English regulations require the lamp to have been burning with the flame at nearly its proper height for at least ten minutes before a test is made.

The final adjustment is made by setting the flame as low as it is possible to have it without having any part of the openings between the three tips forming its top show below the chimney. A good way to get the proper adjustment is to start with the flame a little low; that is, with the lower angles of the openings just showing below the chimney, and with the gas to be tested burning at the proper rate. The photometer disc is then set so that the illumination is equal on both sides, as in making a test, the pentane flame turned up a little, the disc set again, and so on. At first the turning up of the pentane flame will cause it to give more light and the disc will have to be moved toward the gas flame, but a point will soon be reached when the further turning up of the pentane flame causes it to give less light, as will be shown by having to move the disc away from the gas flame. The height at which the pentane flame is thus found to be giving the most light is that at which it should be adjusted, and it should be watched to see that it remains at this height throughout the test.

This Pentane Lamp has been found to be a very reliable standard, and after a little experience with it, it is much more convenient to use than candles. Each lamp must, however, be first standardized by an extensive series of observations against candles, or against another Pentane Lamp the value of which has been previously determined, as none of them give a light of exactly ten candles.

An illustrated description of the Harcourt lamp, giving the dimensions of all parts and also specifications of the manner in which the pentane is to be prepared and tested, can be found in the Proceedings of the American Gas Light Association, Vol. XVI, page xxxix, in the American Gas Light Journal, Vol. LXXI, page 733, or in Progressive Age, Vol. XVII, page 519.

200. Describe a bar photometer, such as is used for determining the illuminating value of gas by direct comparison of the light given by the gas with that given by standard candles.

Ans. The essential features of a bar photometer are a standard gas burner and a standard of light fixed at a definite distance apart, a graduated bar placed between the two lights with its longitudinal centre line in the vertical plane passing through the vertical axes of the lights, a disc perpendicular to this plane and mounted in a box movable on the bar, a meter for measuring the rate at which the gas is consumed, a timepiece for measuring the time, and a balance to weigh the amount of sperm consumed by the candle flames during a test. Two pressure governors, one dry and one wet, a King's pressure gauge and a thermometer for determining the temperature of the gas at the meter are also parts of a fully equipped photometer.

All of the apparatus is mounted on a table of the proper length and of a height that will bring the centres of the lights and the disc, which should all lie in the same horizontal line, on a level with the eyes of the person making the test. Marks are placed on this table fixing, with the aid of plumb-lines suspended from a frame carried on the screens spoken of later, the position to be occupied by the vertical axes of the two lights when they are the required distance apart. This distance is usually taken as either 60 inches or 100 inches. A solid wooden screen extending across the full width of the table and painted a dull black is placed about 12 inches behind each light, and a similar screen, with an opening in the centre large enough to allow the rays of light to reach the disc without any interference, is placed about the same distance in front of each light. The object of these screens is to prevent light from reaching the walls of the room and being possibly reflected back from them.

The graduated bar extends the full distance between the two front screens and is supported by stands fastened to the table. As stated above, the centre line of the bar must lie in the same vertical plane as the line drawn from the centre of one light to the centre of the other. It must also be set at such a height above the table that when the disc-box is mounted on it, the centre of the disc will be in the same horizontal plane as the centres of the lights. The top edge of the bar should be beveled so as to avoid any reflection of light from this edge to the disc, and it is well to also bevel the side pieces fastened on the bottom to support the wheels of the sight box, and all these surfaces should be made a dull black for the same purpose. The bar is graduated according to the law of inverse squares, so that when a single candle is used as the standard of light the candle power of gas can be read at once from the pointer attached to the disc-box. If two candles are used, the readings must be multiplied by 2 to obtain the correct candle power.

The disc most often used is that known as the Leeson disc. It consists of a circular piece of white paper with a star-shaped hole cut out of its centre, placed between two pieces of thin white rice paper. The disc so formed is then put between two pieces of glass, cut from the same sheet so as to be of uniform quality and thickness, and the whole combination put in the blackened metal disc holder and pressed tightly together by means of a wire split-ring sprung into a groove in this holder. The paper must be left perfectly smooth when the disc is in place. Attached to the back edge of the disc-holder are two small mirrors, one on each side of the disc, set with their surfaces at an angle of 60 degrees with the plane of the disc, so that an observer standing directly in front of the edge of the disc can see images of both its faces, one in each mirror. The disc-holder and mirrors are mounted in the disc-box or sight-box in such a way as to be easily reversible, so that either face of the disc can be turned toward either light as desired.

The disc-box or sight-box is a rectangular wooden or metal box mounted on four wheels, which run on pieces provided for this purpose at the bottom of the bar, so that the box can be easily moved back and forth. An oval hole slightly larger than the disc is left in each end of the box, and in the face there is a sight hole, also oval, and about 6 inches long by 3 inches high, through which the reflections of the disc in the mirrors can be seen. A pointer is attached to the box with its point directly below the disc. This pointer passes over the scale on the bar and by means of it the candle power corresponding to any setting of the disc can be read.

The form of burner used varies for different kinds of gas, as explained in the answer to question No. 197. In some photometers the vertical pipe on which the burner is mounted is fixed while in others it is movable and can be brought to, and held in, the proper position by means of a long thumbscrew working through a fixed support on the table into a nut on the burner base. This burner pipe is fitted with two stop cocks, the lower one of the two being very carefully made and provided with a lever handle which is moved by a screw so as to secure a close adjustment. The upper one is an ordinary stop cock by which the gas can be turned on or off without disturbing the adjustment of the lower one.

Various standards of light are employed in photometric work, but only the arrangement of the photometer which provides for the use of candles will be described. It is customary to employ two candles, which are placed in a holder suspended by knife edges from the end of the beam of a delicate and accurate balance which is nearest the disc. The holder is constructed so that the candles are on opposite sides of and equally distant from the continuation of the centre line of the bar. The candles are in some cases held by narrow metal bands in which they can be firmly clamped, while in others they are held in deep cylindrical cups, just large enough in diameter to permit the candles to slip into them, and with adjustable false bottoms, by raising which the flames can be readjusted to the proper height as the candles burn away. From the middle of the cross-piece joining the two candle supports is hung a pan for the reception of the weight by which is determined the rate of burning of the candles during a test. On a knife edge at the other end of the beam hangs another pan into which are put small weights or shot to balance the candles. The candle balance is often mounted so that it can be moved back and forth along the line of the bar, so that the candle flames can always be brought to just the proper position with reference to the middle of the bar and the gas flame. Balances with arms of equal length are to be preferred to those with arms of unequal lengths. Care should be taken to keep the balance in good condition so that it will be sensitive and swing with a steady motion. A pointer attached to the beam at the fulcrum swings over a graduated arc and is over the centre line when the beam is horizontal and the candles just balanced by the weight at the other end.

The meter is a small, wet meter having a large dial, the hand on which makes one complete revolution for each twelfth of a foot passed. This dial is divided into five principal divisions and each one of these is subdivided into ten small divisions. The large divisions correspond to $\frac{1}{60}$ of a foot. A smaller dial divided into twelve equal divisions, each corresponding to one complete revolution of the large hand, is also provided on the face of the meter. Fastened to the side of the meter is a small box with a glass front, on which is a mark showing the water line, and with an opening on top through which water can be added to bring it up to the proper height. This opening is closed by a screw cap. On top of the meter is a small clock, the hand of which travels around the same centre as the large hand of the meter and makes a complete revolution of the dial in one minute. When the hands of the meter and the clock travel at the same speed the gas is passing exactly at the rate of 5 feet per hour, and any other rate of burning can be determined by observing the difference between the speed of the two hands. The clock is worked by a weight and wound by means of a cord. It can be started and stopped as desired by means of a slide. When it is going, it rings a bell when the hand passes the division at the extreme top of the dial. A cord is arranged so that the clock can be started by the observer while standing at the candle end of the table.

Through an opening in the side of the meter a thermometer is inserted vertically into the gas space so that the temperature of the gas passing out of the meter can be noted.

The meter, wet governor and pressure gauge are set on the table back of the solid screen placed behind the burner, and the gas connections are made so that the gas coming from the supply passes first through the dry governor, then to the meter, then to the balanced wet governor and then to the burner. The pressure gauge is provided with four connections, so that the pressure existing at any one of four points can be taken as desired.

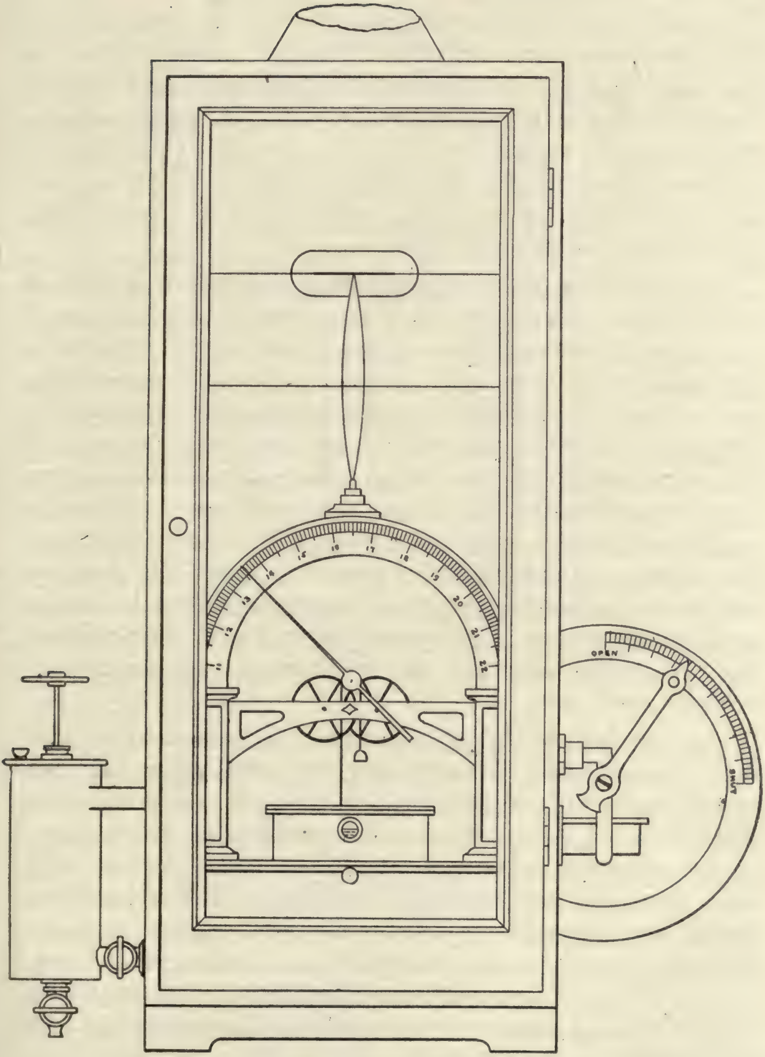
The photometer should be placed in a room that can be kept well ventilated without drafts and from which all outside light can be excluded when making a test. The walls of this room should be painted a dull black to prevent any reflection of light from them to the disc.

201. Give a description, illustrated with sketches, of some form of Jet Photometer used for determining the candle power of gas, and give your opinion as to the reliability of the results obtained by the use of such an instrument.

Ans. The Improved Lowe Jet Photometer is an example of the type of these photometers, which determines the candle power of gas from the pressure required to maintain at a fixed height a flame produced by burning the gas through an orifice of a definite size. It consists essentially of a King's pressure gauge on top of which is fixed a small steatite tip, with a fine circular orifice, through which the gas is burned as it issues from the gas space of the gauge. The gauge is mounted in a wooden case with a glass door. On the back of the case a horizontal line is marked at a height of 7 in. above the top of the tip and a piece of colored glass on the door has its top edge at the same height. A dry governor is placed in front of the stop cock on the gas pipe leading to the gauge, so that the pressure on the supply side of the stop cock is kept constant. The stop cock has a long lever handle; the free end of which moves over a scale marked on a quadrant attached to the side of the case, as shown on the cut. The gauge is made so as to give the least possible friction, and this in connection with the close adjustment of the supply of gas, made possible by the long handle of the stop cock, enables the height of the flame to be regulated so that its tip is exactly in line with the marks on the door and the back of the case, as determined by sighting from one line to the other.

In the old form of these photometers the scale on the gauge is graduated to hundredths of an inch, and the candle power, corresponding to the pressure which exists when the flame is adjusted to the proper height, is obtained from a table furnished with the instrument, either separately or in the form of an auxiliary scale placed below the pressure scale and properly tied into it. In the more modern forms there is no pressure scale as such, the semicircular scale over which the pointer of the gauge travels being graduated to give the candle power by direct reading, as shown on the accompanying cut.

It is of course important that the gauge should show the correct pressure, and to do this the water line must be maintained at the proper level at all times. The adjustment of the water line is provided for by a small cylindrical tank mounted on the side of the case opposite to that on which the gas cock is placed. This tank, which communicates with the gauge by a connecting pipe, is provided with a piston, and the space below this piston being filled with water, the water line of the gauge can be readily adjusted to the proper level by moving



LOWE JET PHOTOMETER.

the piston up or down according as the water is above or below the proper point.

Another style of jet photometer, of which the Jones Jet is an example, determines the candle power of the gas from the varying height of a flame produced by burning the gas through a small orifice at a constant rate or at a constant pressure. The Jones Jet consists of a steatite tip with a fine circular orifice to which the gas is supplied by a volumetric governor, and the candle power scale is marked on a colored glass chimney surrounding the flame.

If illuminating gas could be made at all times of a uniform composition, a jet photometer if once correctly adjusted would give fairly accurate absolute candle-power results. Since it is not possible to make such gas of a perfectly uniform composition, such a photometer cannot be depended upon to give absolute results that are accurate, as even when the tip is of the proper size for the kind of gas to be tested and the readings are correct when the gas has a certain composition, any change in this composition will change the readings even though the illuminating value remains the same. It is obviously entirely out of the question to attempt, as is sometimes done, to use the same jet photometer without change of tip for both coal gas and carburetted water gas, or a mixture of coal gas and carburetted-water gas.

The true field of the jet photometer is to furnish a rapid method of obtaining frequent tests of candle power that can be compared with one another and thus afford a check upon manufacturing results that cannot be obtained by comparatively infrequent tests made upon a bar photometer. But even when used in this way the reading of a jet photometer should be compared every day or two with the candle power as shown by a bar photometer in order to be certain that, through change in composition of the gas or in the size of the orifice in the tip, these readings do not vary too much from the actual candle power of the gas.

SECTION IV.—DISTRIBUTION SYSTEM AND CONSUMERS' APPLIANCES.

Street Mains.

202. What are the respective advantages and disadvantages of cast and wrought iron pipes for use as gas mains?

Ans. The advantages of cast iron, as compared with wrought iron, pipe, for use as gas mains, are greater ability to withstand any corrosive action of the soil in which it is laid, and consequent longer life, greater thickness for equivalent internal diameters, giving a better joint for service connections tapped directly into the main, and, in sizes from 6 in. to 30 in. inclusive in diameter, smaller first cost. The disadvantages of cast-iron pipe are, the necessity for a greater number of joints of a form more difficult to make tight originally, and to keep tight throughout the life of the pipe, than is the form of joint used in wrought iron pipe, and the brittleness of cast iron, which renders it liable to break under shocks from extraordinary traffic on the street in which it is laid, or from strains thrown upon it through subsidences, due either to a disturbance of its foundation or to this foundation being originally insecure. The advantages and disadvantages of wrought iron pipe as compared with cast iron are of course the converse of the above.

In good soils cast iron will last indefinitely and even under the worst conditions it will have a life of some years. Comparatively little wrought iron pipe has been used for gas mains and none of this dates back far enough to furnish conclusive data as to the number of years that can be safely counted upon as the life, under ordinary gas distribution conditions, of such pipe when covered with a good protective coating. Experience with coated services shows, however, that when the conditions are at all bad, wrought iron corrodes much faster than cast iron, and that even under comparatively favorable conditions a very perfect coating is necessary to make a life of twenty to thirty years reasonably certain.

The greater thickness of cast-iron pipes permits the securing of sufficient depth of thread to make a good screw joint in the wall of the pipe itself, so that there is no necessity for using the service clips or saddles, without which a good joint cannot be obtained with wrought iron pipe. The use of these clips adds not only to the cost of the services but also to the opportunity for leakage at the service connections.

In the smaller sizes, 3 in. and 4 in., however, wrought iron pipe can be laid, under normal conditions of price, more cheaply than cast-iron pipe, and in small towns or the residential suburbs of large cities, where the soil is good, the services will never average less than 50 ft. apart and the probable consumption will never exceed the capacity of the above sizes, the advantages of wrought iron outweigh the disadvantage of possibly shorter life, and it is good practice to use it.

Another place where the use of wrought iron is advantageous is in the case of a line to be laid up a hill where the ditch would have to be blasted out of rock, and where there is an opportunity to use a ditch already made for a sewer or a water pipe. A line of cast-iron pipe could not be maintained in such a location, while the wrought iron pipe is strong enough not to be broken by any settling, and the line being laid on a slope there is little danger of its becoming trapped.

Wrought iron pipe is also preferable for use on bridges and in other exposed places.

203. What do you consider the smallest size of cast-iron pipe which it is advisable to lay for street mains, and what weight per foot or per length of 12 feet do you consider suitable for this size of pipe?

Ans. It is not good practice to lay any cast-iron pipe of a smaller diameter than 4 in., except in localities where it is reasonably certain that a smaller pipe will be able to deliver for an indefinite period, without undue loss of pressure, all the gas required in the territory to be supplied.

A good average weight for 4 in. cast-iron pipe is 220 lb. per length of 12 feet, or about 18 lb. per foot. For use in very small towns lighter pipe can be employed, while in some locations in large cities heavier pipe is needed, but for general use the above is, as stated, a good average weight.

204. Give a list of the various joints employed for connecting together the separate lengths of cast-iron gas pipes, and state their respective advantages.

Ans. In England and on the continent of Europe a great variety of joints for cast-iron pipe have been devised and to a certain extent used. These include movable flange joints, clip joints, collar joints, screwed joints, bell and spigot joints in which the joint is made by means of a vulcanized rubber ring, and bored and turned joints as well as the fixed flange joints, bell and spigot joints of lead or cement and ball and socket joints, which are practically the only joints used in this country, and are, therefore, the only ones considered in this answer.

Flange joints allow of the easy removal, when desired, of any one of the various pieces of pipe. They are, however, very rigid, and their use is confined to lines of pipe above ground and at the works. On long, straight lines of flanged pipe one or more expansion joints should be provided to relieve the pipe of the strains that would be thrown upon it by its expansion and contraction under the influence of changes in temperature.

Ball and socket joints are expensive and are used only for lines where great flexibility is necessary, as in laying pipes under water.

For ordinary street main work, bell and spigot joints are used almost exclusively in this country. The joints are made sometimes with lead and sometimes with cement.

The lead joint, while as a rule more expensive than the cement joint, has the advantages of being more easily cut out, more easily repaired, and of allowing the pipes to expand and contract, under the influence of changes of temperature, without fracture, since the lengths can move in the joints.

On the other hand, the cement joint is cheaper and more rigid than the lead joint, and when properly made will remain tight under almost any possible conditions. A line of pipe laid with cement joints if exposed to changes of temperature will not show small leaks at the joints as will one laid with lead joints, but, on the other hand, it is more liable to fracture.

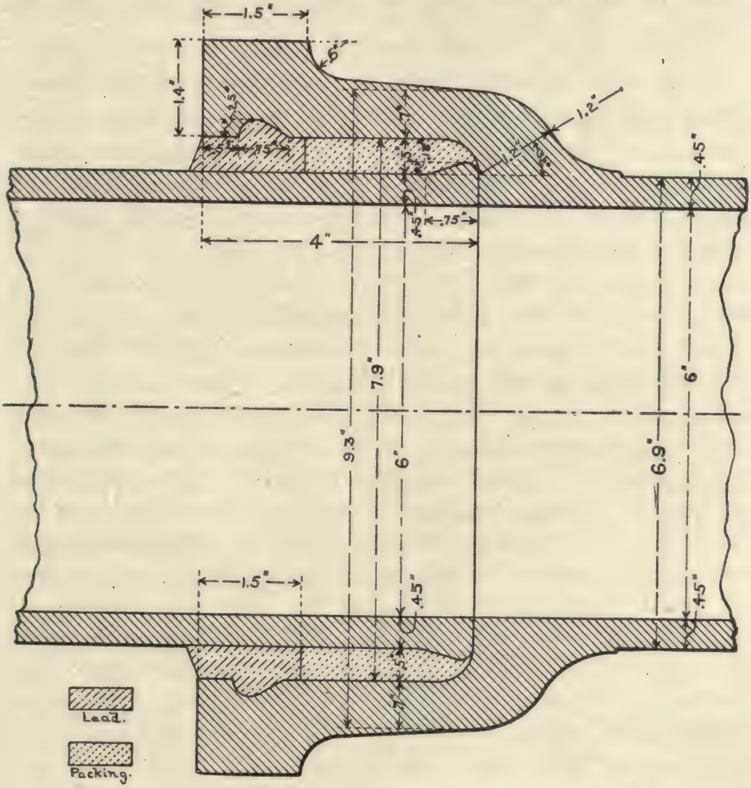
In most instances the choice between lead and cement joints is determined by the relative disadvantages of a number of small leaks and of one large leak, which latter will be more quickly detected, but, because of allowing more gas to leak in a given time, is more liable to cause damage. In one large city lead joints are used in the heart of the city, where gas from a leak might collect in closed spaces, and cement joints are used in the outskirts, where the conditions are more favorable for the gas from a leak passing away into the open air without forming an explosive mixture in a confined space. A frequent practice is to lay the pipes with cement joints, but at intervals of from six to twelve lengths to put in a lead joint to act as an expansion joint—the location being marked and noted, and the lead joint occasionally examined.

205. Give a description, illustrated with a sketch of a longitudinal section of both spigot and hub showing outside diameter of spigot, all dimensions of the hub or bell, the shape of the lead groove in the bell, and the depth and finished shape of the lead, of the making of a lead joint in a 6 in. cast-iron main. Give also the amount of lead and packing used and the length of time that should be required to do the work.

Ans. In making a lead joint in a 6 in. cast-iron main, the first step in the operation, after the spigot end of one length has been inserted in the bell of the other and the length driven home, lined up and fixed in place by the tamping of a little dirt around the middle of it, is to fill solidly with packing, a portion of the joint space between the spigot and bell, the amount of space so filled being determined by the depth of lead which it is desired to have. For ordinary straight work with 6 in. pipe, the depth of lead may be taken at 1½ in., and the joint space will therefore be filled with packing to a point 1½ in. back from the face of the bell.

Jute packing, either plain or tarred, is usually employed. Packing which has been allowed to absorb a small quantity of tar can be driven tighter than plain packing, but tar being cheaper than jute it is hard to avoid the presence of too much tar in tarred packing, and for this reason plain packing is often given the preference.

A sufficient number of strands of packing should be twisted to form a rope of a diameter a trifle larger than the width of the joint space, and this should be cut into pieces of such length that the ends will come into close contact when a piece is placed around the outside of the spigot end of the pipe and pulled up tight. One of these pieces is used to lift the spigot end as it is inserted into the bell of the pipe previously laid, and is sent home with it, thus keeping the spigot central in the bell and avoiding the necessity of wedging it up after it is in place. This piece of packing is driven solidly into place in the bottom of the joint space by means of a caulking hammer and packing iron, and other pieces are inserted one



SECTION OF 6-INCH BELL, SPIGOT AND LEAD JOINT.
AMERICAN GAS LIGHT ASSOCIATION STANDARD.

at a time, the joint in each ring being put, say, one-fourth of the circumference away from the joint in the preceding ring, and each driven home, a sufficient number being used to fill the joint space to the required depth, leaving 1½ in. for the lead. The packing must be driven hard and the finished layer must be of uniform depth, so that the lead space will be uniform all around the pipe.

A clay roll or other form of joint runner is then placed around the spigot end of the pipe, being brought tight against the face of the bell, and so set as to leave a triangular space, having its base on the pipe and its apex on the face of the bell slightly above the inside edge, which the lead can fill and thus make it certain that, when driven, the joint will be of the shape shown on the cut. Molten lead is run into the joint and this space until both are completely filled and the lead stands above the highest point on the inside edge of the bell, the lead being poured in through an opening or "gate" left on top of the pipe. When the lead has hardened the joint runner is removed and the "gate" or lump of lead left where the opening for pouring was made is cut off. The lead is then chiseled all around the pipe with a cold chisel and caulking hammer. This separates the lead from the surface of the pipe and makes a groove in which the first caulking tool, the face of which is about $\frac{3}{16}$ in. thick, can fit. The lead is driven all around with this tool and then with tools successively increasing in thickness by about ⅛ in. until the full width of the joint has been reached. The work with each tool should be begun at the bottom of the pipe and carried around each way, finishing up at the top. The thickness of the last tool used should not be greater than the width of the joint, and the driving with this tool should cut the lead off sharp with the inside edge of the bell, otherwise there is danger that the force of the blows will be expended against the face of the bell instead of doing the full amount of work that it should do in compressing the lead in the joint. In order to have the tools fit the joints exactly it is well to have them made in sizes varying in thickness by $\frac{1}{16}$ in., though it is only necessary to use on any joint tools varying by ⅛ in., the proper sizes being selected. The position in which the tools are naturally held when caulking the joint will give it the finished shape shown on the cut, if the joint runner has been put on properly and sufficient lead used.

There will be required for making a 6 in. lead joint about 7 to 8 lb. of lead, and 7 to 10 oz. of jute packing. A good workman should be able to average nearly 3 joints an hour for a day's work.

The cut shows the spigot and bell of the standard dimensions adopted by the American Gas Light Association in 1905.

206. Describe the making of a cement joint in 8-inch cast iron hub and spigot pipe, giving approximately the quantity of materials used and the time it would take a man to make the joint. Give a sketch showing a section of the joint with dimensions.

Ans. Use Portland cement. Natural cements are not uniform in quality, and, as a rule, are too quick-setting to permit of their use with safety. In selecting the brand, take a relatively quick-setting Portland. If the cement sets too slowly there is danger of the finished joint being disturbed before setting.

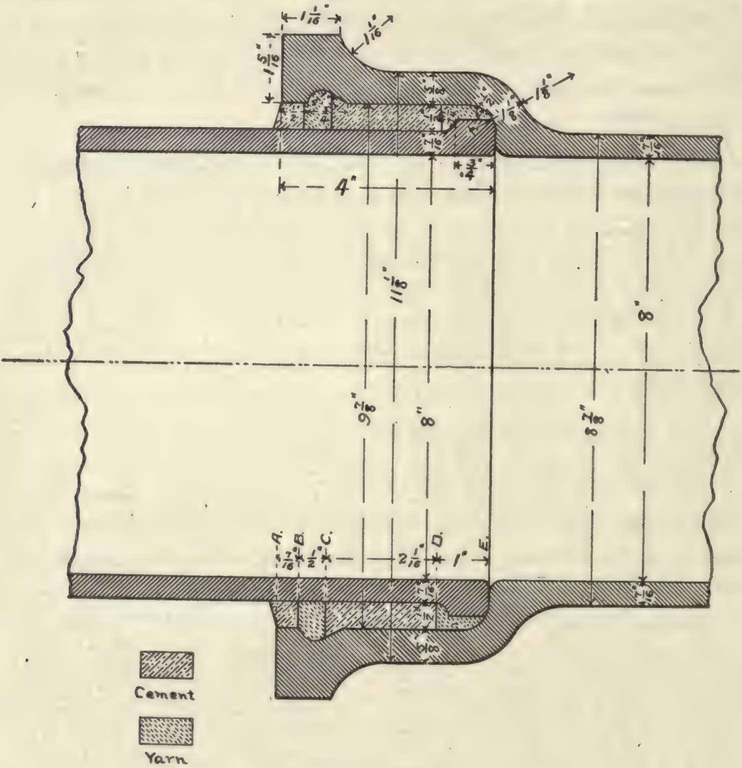
Use the cement neat—no sand.

Use the cement as dry as possible, so that it requires hammering the yarn against it in order to bring the moisture to the surface. When sufficient water is added the cement will still appear crumbly in the pan, and will just retain the impression of the fingers when squeezed in the hand.

The cement should be used immediately after mixing; if it lies unused over five minutes it should be discarded. The cement remaining in the pan should be entirely removed before mixing up any new cement. In mixing cement, first determine the quantity required for one joint, and the quantity of water required for this cement, and then always use the cement and water by measurement.

Use jute yarn, untarred. When the joint is made the yarn and sides of joint may be moist or damp, but should not be wet.

Great care should be taken to have the surface of the bell and spigot making up the joint as clean as possible. If there is any appreciable rust it should be scraped off with a wire brush, and, if necessary, gasoline should be applied to cut out the rust still further, this being done at least a day before the joint is to be made in order to give the gasoline time to evaporate.



CEMENT JOINT.

The finished joint should consist of one roll of yarn of the exact circumference of the pipe, twisted and driven tightly to the bottom of the bell, occupying approximately the space D-E; then a solid mass of cement extending to a point about 1 in. back of the face of the bell, occupying the space C-D; then a second roll of yarn occupying the space B-C; then a facing of cement, occupying the space A-B. Do not make a large fillet extending to the outside diameter of the bell. In making the joint after the yarn D-E has been driven in tightly, the cement should be shoved in with the hands, on which are rubber gloves or mitts, preferably the latter, until the whole space A-D is filled as tightly as it is possible to do so with the hands, being particular to fill the space completely. A wooden pusher, shaped something like a yarning tool, is useful for pushing back the cement after it has been put in with the hands. Sometimes a roll of yarn is used to drive the cement back, the yarn being withdrawn, more cement entered, and the process repeated until the desired quantity has been entered. The second roll of yarn, B-C, is then put in and driven back by means of a tool similar to a yarning tool, but with a blunter edge, until it is not possible to drive it back any more, which condition is generally obtained when it has reached the position B-C as shown in the figure. The space A-B is then filled with cement. The hard driving of the yarn B-C is very important as being necessary to so compact the cement C-D that there will be no chance for gas to get either through it or between it and the iron.

After the first yarn is in, and before the joint is made, the pipe should be thoroughly bedded and tamped in between the bell holes to prevent any movement of the joint after it is made.

When the joint is made, it should be protected from the sun. As few joints as possible should be made in the rain. If work is done on a hot day, and the pipe has been exposed to the sun so that it has become quite heated, it is advisable to cool it off by the application of water to the inside of the bell and the outside of the spigot, care being exercised not to have any water left in the bottom of the joint, the effect of which will be to make the cement too wet.

All joints should be tested before being covered up. The best test is made by connecting gas pressure to the new pipe, through a meter, thus measuring the amount of leakage, if any. If the meter indicates leakage, the leaks should be found by using soapsuds on the joints. Fire should never be used. The joints should be tested only after the cement has set sufficiently to prevent its being hurt by the soapsuds; where feasible, this should be on the following day.

To make each joint there will be required on an average 5 ounces of yarn and 1¼ quarts of cement, and the time required will be 15 minutes for one man. This time is the average time that would be taken per joint over a whole day's work.

Cement joints are also made in a similar manner to the joint described, but with the use of less cement and more yarn. While it is possible to obtain tight joints in this way, it is not thought that the joints obtained are as good as those made by the method described above.

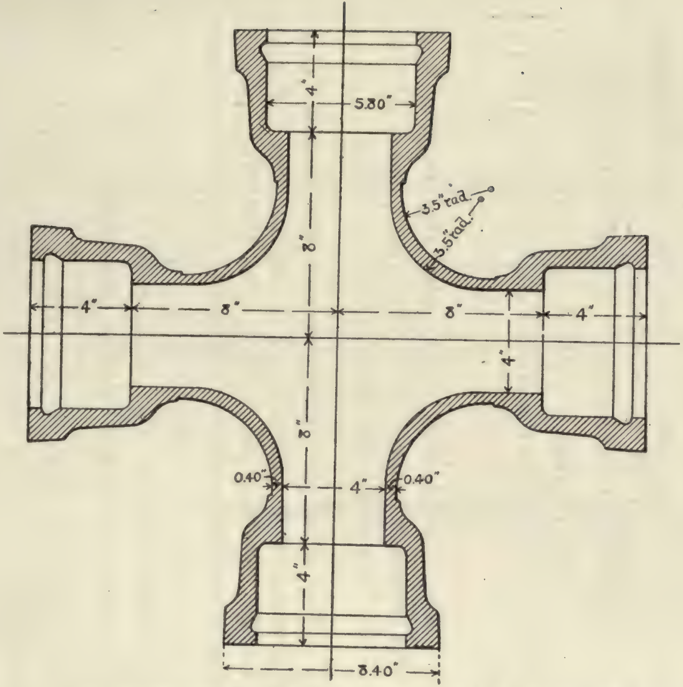
207. Give a description, illustrated with sketches, of a cross, or four-way branch, for four-inch cast-iron pipe, giving the dimensions to be used when it is provided with bells, and also those to be used for flanged ends, including the number of bolts and diameter of bolt circle.

Ans. A four-inch cross or four-way branch made according to the standard is shown on the accompanying cut. The bell cross has a bell on each outlet unless otherwise specified, although any desired combination of bell and spigot ends can be made. The distance from the centre line of each run to the bottom of the bells on the other run is 8 in. The depth of the bells is 4 in., and the other dimensions are as shown on the cut.

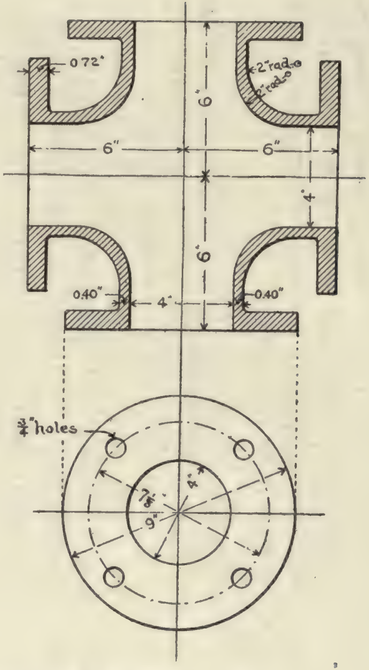
For a flanged cross the distance from the centre line of the runs to the faces of the flanges is 6 in. in each case. The outside diameter of the flanges is 9 in., the diameter of the bolt circle is 7⅛ in., and the flanges are drilled with four ¾ in. holes placed as shown.

208. Give a description, illustrated with a sketch showing all the dimensions of drip and cover and the arrangement of the pumping pipe, of a 6-inch line drip.

Ans. A line drip is a cylindrical vessel made of cast iron. It has a solid bottom and is closed at the top by a removable cover which is usually fastened in place with a lead joint, the lead being run and caulked into a joint space between the



FOUR-INCH CROSS WITH FOUR STANDARD FOUR-INCH BELLS.



FOUR-INCH FLANGED CROSS.

cover and the drip. Hubs or bells of the proper size are cast on opposite each other near the top, and by means of these the drip is inserted into the pipe line at a low point and forms part of the line, the gas passing through its upper part while the condensation falls to the bottom.

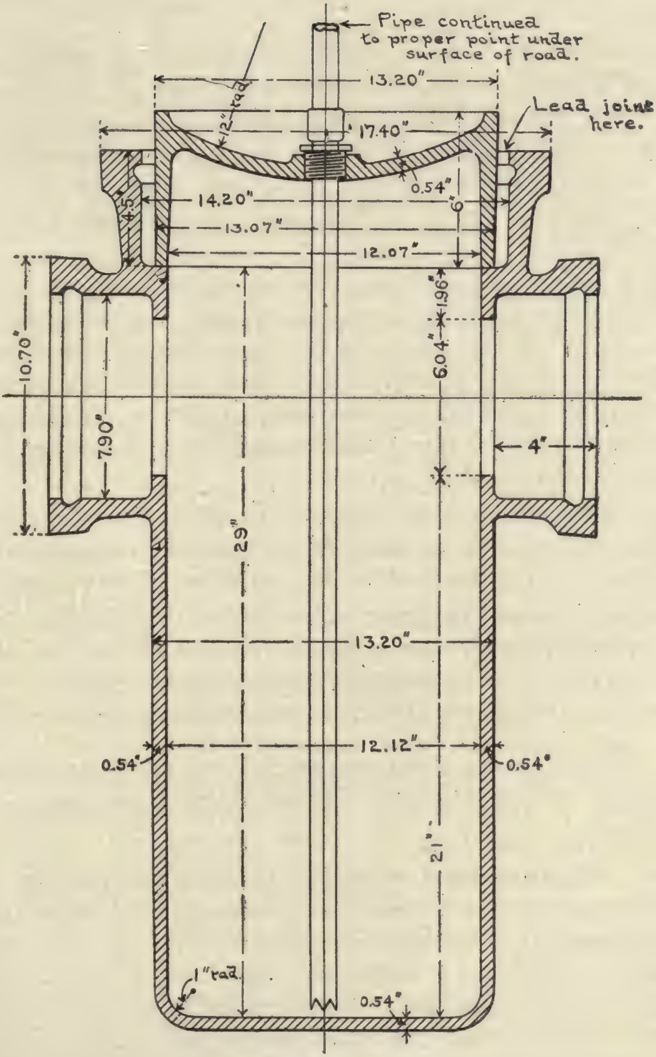
The condensation is pumped from the drip by a vertical wrought iron pipe, ¾ in. or 1 in. in diameter, screwed through a 1¼ in. × 1 in. or a 1¼ in. × ¾ in. bushing which is screwed into the cover. The lower end of the pipe is serrated and almost touches the bottom of the drip, and there is screwed on the end projecting above the cover another piece of such a length that the upper end is just below the level of the roadway, in which is set a drip-box which protects the pipe and at the same time renders it accessible. When the drip is to be pumped, the cap, by which the upper end is closed, is removed and the drip pump screwed on. Sometimes the pumping pipe instead of being carried up vertically to the surface is run under the surface to the curb and then brought to the top.

The cut shows a section of a 6-inch drip made according to the standards adopted by the American Gas Light Association in 1905.

209. What considerations determine the depth at which street mains should be laid, there being no question of interference with any other pipe systems?

Ans. The principal considerations that determine the depth at which street mains should be laid are their protection from damage by the traffic passing over them and from the influence of the changes in the temperature of the atmosphere.

In Canada and the greater portion of the United States the depth at which mains are laid is governed by the latter consideration, since the depth required for protection from frost is greater than that required for protection from the traffic carried on along the roadway above the pipes. The customary rule is to keep the top of the mains just below the normal frost line. In the vicinity of New York City this requires the mains to be laid with three feet of cover, while in Canada and



6-INCH LINE DRIP
BELLS MADE ACCORDING TO STANDARD.

the Northern and Northwestern parts of the United States, in which the winters are very severe, the depth may reach six feet.

In the Southern States, where the winters are mild, the changes in temperature are of minor importance and the mains need not be laid any deeper than is necessary to protect them from the traffic passing over them. For this purpose a depth of 24 inches is sufficient, except in business streets where the traffic is apt to be heavy, in which case 2 feet 6 inches of cover should be given.

When the temperature and traffic conditions are such as to permit of the mains being laid comparatively near the surface, the character of the pavements, either already existing or which will probably be laid. in the future, must be taken into consideration and the mains laid deep enough to obviate any danger of the service pipes being interfered with during the laying or repairing of the pavement.

Other pipe systems and subsoil structures also affect the problem at times, but, as stated in the question, these were to be left out of consideration for the purposes of this answer.

Nothing is gained by going below the depth determined as above, and the deeper the mains the greater is the expense incurred both in their installation and their maintenance. It is therefore advisable not to go any lower than is necessary.

210. When laying street mains, how would you test the tightness of the work before filling in the ditch and covering up the pipe?

Ans. When the piece of main being laid is an extension of an old main it is usually connected to the old main when the work is begun and the test for tightness is made with gas pressure. After such a length has been laid as to warrant going to work to fill in and close up the ditch, the open end of the pipe should be tightly plugged and the pressure allowed to come on the new pipe by removing the bag or stopper by which the gas has been shut off. Each joint should then be painted with soapsuds and examined for leaks, which will be indicated by bubbles at the points of leakage. Especial attention should be paid to the bottom of the joints. Any joints found to be leaking must be gone over and again tested. When all are tight the ditch can be filled in.

In testing in this way no attempt is made, as a rule, to test for leaks in the pipe between the joints, but if each length has been carefully hammered before it is lowered into the ditch there is only a slight chance of there being any such leaks. When the work is important enough to warrant the extra expense the new pipe can be left separate from the old and a temporary connection made through a meter. Then after the pressure has been equalized on both sides of the meter, observation of the test hand will show whether any more gas is passing and thus indicate the presence or absence of leaks. If the meter shows that there are leaks they must be located by an examination of the joints and pipe, using soapsuds on the joints as above. When testing in this way it is necessary to see that there is no large rise or fall in the temperature of the piece of pipe under test, since the resulting change of volume of the gas would affect the indications of the test meter and might make the pipe appear tight when there were really some leaks on it, or make it seem to leak when it was tight. The proper allowance must be made for unavoidable change in temperature. After passing the test the new work is connected to the old main, generally with a sleeve.

When gas pressure is not available, or even in some cases where it can be had, but a test at a higher pressure than can be obtained from it is desired, the pipe is put under an air pressure by pumping air into it until a pressure of two to three pounds, equal to approximately 54 in. to 81 in. of water or 4 in. to 6 in. of mercury, is reached. The joints should then be examined for leaks as described above, and the pressure watched to see if it holds up. The indications afforded by the steadiness of the pressure are as liable to be rendered worthless by change of temperature as are the meter readings, when a meter is used, and the temperature conditions must be noted and allowed for when the holding up of the pressure is relied on as the sole means for determining the tightness of the pipe, and for certainty it is necessary to examine the joints in each case.

In connection with the tests each caulker, where there are more than one on a job, should be made to mark with his name or number every joint which he makes, so that every imperfect one can be charged to the right man. The knowledge that all poor work will be immediately discovered and placed to their discredit makes the caulkers more careful with their work, and thus secures a better job, even apart from the discovery of leaks by the test.

211. Why is it necessary to provide for draining all mains and pipes through which gas travels, and how is this done?

Ans. Gas as it escapes from the retort, or generating apparatus, contains water vapor and condensable hydrocarbon vapors, which are deposited in the form of liquids as the gas cools down during the process of condensation. And even though all the condensable hydrocarbon vapors may have been removed during this process, the contact with the water in the water seals throughout the apparatus, and with that in the holder tanks, makes it probable that the gas entering the street main system will be, almost, if not fully, saturated with water vapor at the temperature it then possesses. When this temperature is reduced, during the passage of the gas through the mains, some of the vapor will be deposited in the pipes in the liquid form and, unless provision is made for drawing this off as it deposits, the pipes will ultimately fill up and the flow of gas through them will be cut off. It is, therefore, necessary to lay all gas pipes on a slight incline without any sags or traps and to provide means for removing the liquids accumulating at the low points. When the pipes are above ground in the works the liquids can usually be run off through constantly flowing syphons, but when the pipes are underground it is necessary to provide drip pots or drips into which the condensed liquids run and from which they are pumped at intervals.

212. Having provided drip pots at the proper points in the Street Main system, what further precaution is necessary to prevent trouble from accumulation of condensation?

Ans. After having provided drip pots at the proper points in the Street Main system, it is further necessary that the liquids that condense in the pipes and flow into the drips shall be pumped out at regular intervals. The length of time that it is safe to allow to elapse between two consecutive pumpings of any drip must be determined by actual experience, and should always be sufficiently short to avoid the possibility of the liquids accumulating in the drip pot between pumpings to a height that will allow them to overflow from the drip into the pipe in which it is inserted. In the case of drips in the works, or those in the vicinity of the works on the trunk mains supplying the district, the intervals between pumpings will probably vary from a few hours to one week, while in the extreme outer part of the district it is very often safe to allow the drip pots to go unpumped for a year. All drips, no matter how small the amount of liquid they collect, should be examined at least once a year. In case the rate at which the liquids accumulate in any drip pot shows a sudden increase an investigation should be made, the cause of the increase determined and the proper steps taken to remove this cause.

213. In putting in gas piping that will be exposed to extreme cold, such as the risers in street lamp posts or the portions of mains on bridges, what method would you adopt to guard against the obstruction of the pipe by frost?

Ans. Obstructions to gas pipes from frost may be guarded against either,

By enlarging the portion of the pipe in which the frost tends to accumulate to such an extent that a passage of sufficient size will remain for the gas even after the frost has accumulated on the interior surface of the pipe to a thickness that makes it an efficient non-conductor of heat and so prevents any further formation, or,

By covering the outside of the pipe with a non-conducting coating which prevents the gas from being cooled to the frost-producing temperature, or,

By providing means for readily removing the frost when it has collected in sufficient quantity to begin to unduly restrict the flow of gas through the pipe.

The first method is preferable wherever the extra size of pipe called for is neither inconvenient nor expensive. It is applied to lamp risers by the use of about thirty inches of 1½ in. pipe, called an "anti-freezer," extending up from the service to about one foot above ground. The remainder of the lamp riser is of the usual size, ¾ in. or ½ in., and the greater area of the 1½ in. pipe allows much frost to be deposited in it before it is closed up, and it is found in practice, that in the latitude of the Northern States, the winters are seldom severe enough to cause the anti-freezer to become stopped up. The location of the anti-freezer, just where the gas goes through the cold ground and first strikes the air, insures that all condensation will occur in it. For bridge crossings, where the main is small, 6 in., or less, in diameter, this method is applied by increasing the diameter of the pipe by 2 in. from a point in advance of that at which the exposure to cold begins on one side to a point beyond that at which this exposure ends on the other side. If the pipe rises from the ground to cross on top of the bridge, the larger size should be used from the beginning of the rise on the one side to the end of the drop on the other, while if the pipe crosses under the bridge and on practically the level at which it is laid on the approaches, the enlargement should be made on each side at a distance back from the face of the abutment at least equal to the depth to which the pipe is covered plus one foot. When wrought iron pipe is used for the crossing, a piece of pipe of the same size as the main in the ground is sometimes inserted loosely in the enlarged portion, as a precaution against the obstruction of the passage by accumulations, on the bottom, of frost shaken loose from the top, the two pipes being kept concentric by proper distance pieces. The frost forms in the annular space and leaves the inner pipe entirely unobstructed and surrounded by a good non-conductor.

When the pipe is small and the conditions are such that a non-conducting covering on the outside of the pipe can be applied cheaply and will not be exposed to undue wear and tear, the second method is preferable to either of the others.

The third method, that of providing means for dissolving, or otherwise removing, frost as it forms, is to be preferred to the others in case of large pipe on bridges. Where the supply demands a pipe 6 in. or larger, and the climate is so severe that frost enough would form to seriously diminish or to stop the flow of gas, openings should be provided in the bridge line for the introduction of a solvent for the frost, such as wood alcohol. Ordinarily, holes tapped in the line at high points, say about twenty feet apart, will suffice. One or two such holes should also be provided in case of emergency, even when the method of enlargement is adopted. In very large lines, 16 in. and over in size, tees may be put on each side of the bridge where the line comes out of the ground, the free outlets of these tees being made flanged and closed with blank flanges. This would provide against extremely large deposits of frost, for full access to the line would be obtained by removing these flanges. There should be a valve on each side of the bridge to permit the bridge line to be cut out. Where the bridge line furnished the only supply to the district on the farther side a temporary by-pass line would have to be laid before the valves were closed.

214. How do sharp turns in a pipe affect the amount of gas that it will deliver?

Ans. Sharp turns in a line of pipe materially increase the friction between the current of gas and the sides of the pipe, and as the amount of gas that any given size pipe will deliver under a given loss in pressure decreases as the friction increases, the greater the number of sharp turns, the less gas will the pipe deliver for the same length and diameter and the same loss in pressure.

On pages 176 and 177 of Volume XVI, "Progressive Age," and on page 679, Volume LXVI, "American Gas Light Journal," will be found some remarks bearing upon this question of decreased flow due to sharp turns.

215. Describe a system of records by means of which full information regarding the location, size, etc., of street mains can be economically filed in such shape as to be available for quick and ready reference.

Ans. The question of street main records naturally divides itself into two parts, the obtaining of the data and the recording of them in a convenient, accessible shape.

On new work the obtaining of the data is a very easy matter, although it is often overlooked. As each piece of main is laid, measurements showing the line on which it is run, its depth below the surface of the street, the location of all fittings, and that of at least one bell on each block should be made and recorded. The measurements showing the line along which the main is run are generally taken from the nearest curb, but for unpaved streets it is probably preferable to take them from the property line, as this is less apt to change. The measurements along the line itself giving the location of fittings and of the bells, should be made from a zero point, such a point being adopted for each city block. One of the property lines of the intersecting street makes a good zero point, care being taken to take the corresponding line for each block along each street, and as far as possible for every one of a number of parallel streets, and to make all measurements in the same direction. Thus, on streets running north and south, the zero point should be either the south line or the north line of the intersecting street in each case, and not the south line in some cases and the north line in others. If no cut lengths are put in between intersections, except immediately at the fittings, it is only necessary to locate the bell at which the full lengths begin and to make a note of the normal distance between bells. If a cut piece is required away from a fitting, the bell at which the full lengths again begin should be located. This information as to the location of bells is valuable when the work of barring for leaks is to be undertaken, especially where the mains to be barred over are under pavement.

To make it easier to report the information noted above as being necessary, the person whose duty it is to obtain it should be provided with copies of a special form upon which it can be entered in writing as well as by means of sketches. Different forms are used by different companies, some using simply a card 5 in. x 8 in. on which a heading is printed as shown and the remainder section-lined, that is, divided by light blue lines into squares, to make it easy to make sketches upon it, while others use cards on which, in addition to the heading, is printed a diagram of a block with the two intersecting streets.

SKETCH CARD OF STREET MAIN CONNECTIONS

..................Side ....Street
From .... To .... St.
No. .... Date .... 19........
Commenced .... 19........ Finished .... 19........

The latter form does not meet the case of intersections at angles greater or less than a right angle. With either style of form one is filled out for each block of pipe laid and is used to post the information on the permanent record.

In the case of old work for which there are no records, every street opening made by the company, and all those made by others, that are noticed, should be taken advantage of for the purpose of securing the information desired. For this purpose the foreman of every service gang and any other employees, including the superintendent, who are apt to come across such openings, should be equipped with small cards, printed as

STREET MAIN INFORMATION CARD.

Nearest House No. ______________________________ St.
Nature of work ______________________ Date ____________ 190
Size ______________ Depth to top ____________ Ft. ________ Ins. ________
Distance ____________ Ft. ________ Ins. ____________ of ______________ Line
Drips towards ____
Kind of soil ____
Remarks ____
____
____
______________________ ○ ______________________
Sign here ____

shown, on which to enter the measurements taken. If an intersection is exposed a sketch can be made on the back of the card. Information as to drips and valves can be put as secured on other cards, printed as shown, and, if desired, sketches of connections to them can be made on the back of the cards. These drip and valve cards should also be used to report the location of drips and valves put in during the course of new work.

DRIP RECORD

Nearest House No.______________________________St.

________________________Date____________190

Location________Feet________Ins.________of________Line

______Ft.______Ins.______of________Line of____________St.

SIZE OF MAIN________Depth to Top______Ft.______Ins.______

______Ft.______Ins.______of________Line________

Style of Drip________________________________

Remarks____________________________________

____

____________________○____________________

Signed________________________________

VALVE RECORD

Nearest House No.______________________________St

________________________Date____________190

Location________Feet________Ins.________of________Line

______Ft.______Ins.______of________Line of____________St.

SIZE OF MAIN________Depth to Top______Ft.______Ins.______

______Ft.______Ins.______of________Line________

Kind of Valve________________________________

Opens to the________________________________

Remarks____________________________________

____________________○____________________

Signed________________________________

When these cards are handed in, either to the record department in the case of a large company, or to the superintendent where the company is so small that this official is also the draughtsman, the information contained in them should be posted to the street main maps and the cards then filed for future reference. The filing is often done according to geographical location, the streets being arranged alphabetically, and the cards for each street in the order of the street numbers. It may also be done by giving a number to every city block or every section of road in the territory, these numbers being marked on a wall map used as an index map, and filing all cards referring to any city block or section of road under the proper number, sub-numbers being used when two or more cards are filed for any block. Thus, if the block were No. 100, the first card would be No. 100–1, the second No. 100–2, and so on. When information is wanted for any locality, the number is found from the index map and it is very easy to find the card in the file. For comparatively small new systems and where the street numbers do not run by blocks, and, consequently, do not afford any indication of the exact location on the street of any number, or where there are no street numbers, as in small towns and along country roads, the block number system is the best. For very large, old systems with no records there is not much choice, and the geographical filing does not involve any preliminary work in assigning block numbers.

A map showing the whole territory on one sheet, if possible, and on not more than two or three sheets at the outside, should be made on tracing cloth. A good scale for this map is 300 feet to the inch. If the blocks are to be numbered, the numbering should be done on this tracing. Except for the names of the streets and the block numbers, all of which should be put inside the property lines and not in the spaces showing the streets, the tracing is to be left unmarked and black on white prints are to be made from it for use as maps. On one such print every street main in the system should be entered, the different sizes being distinguished either by the use of different colored inks, or of different combinations of dots and dashes in the same color. When using different colors it is well to work from lighter to darker colors as the size increases, so that when an old main is replaced by a larger one, the darker color will cover the lighter one without any need of making an erasure. This map will merely show the fact that at a certain location there is or is not a gas main, and if the main is there will give its size, but it will not show any details of location or construction. If desired, similar maps can be made to show trunk mains, nothing smaller than 8-inch being put on, and the general location of drips and syphons and valves, a separate map being used for each special purpose.

For recording details an "insurance map" of the territory should be bought whenever one is available. These maps show all settled parts of a city on a scale of 50 feet to the inch and the unsettled portions on a scale of 100 feet to the inch, and consist of a number of separate sheets bound in book form, each sheet covering several squares. On them are shown all buildings, and when they are purchased from the company that publishes them, arrangements can be made to have them kept posted as to new buildings and changes in old buildings. They sometimes also show water mains, and in ordering them it should be stipulated that water mains are not to be shown on the set furnished. If no insurance map or other already prepared large scale map be available, a special large scale map in sheets will have to be made to take its place. On whichever is used should be shown the size and detail of every street main. The sizes may be marked in the same way as on the small scale map, or all the mains may be put in in solid black lines and the size indicated by figures and the use of lines of different thicknesses. The distance of the pipe from the property line and the position of all fittings, drips, valves, sleeves, etc., should be located by writing, on the map, the proper dimension lines. The scale should be large enough to permit this to be done with clearness in the case of all distribution systems, except those in a few of the very large cities where the underground situation is such as to make it necessary to use a large number of fittings, closely spaced. Rubber stamps of the proper shapes can be used for marking the various fittings to facilitate the work. With cards made out and filed and maps drawn as described above, there will be no trouble in finding quickly and easily any information as to the street main system that is desired, and the information will have been obtained and filed as economically as it is possible to do it.

Articles which contain good ideas on the subject of street main records and maps will be found as follows: American Gas Light Journal, Vol. LXVI, page 481; Vol. LXX, page 482; Vol. LXXIV, page 449, and Progressive Age, Vol. XVII, page 128; Vol. XIX, page 114.

216. Why is it important to regulate the pressure on street mains?

Ans. It is very desirable that the gas should reach the consumer at a uniform pressure, or a pressure as nearly uniform as it is possible to have it under working conditions, since unless this is the case he cannot get good results from his gas consuming appliances. If the loss of pressure in the street mains between the works and the consumer was always the same, the maintenance of a uniform pressure at the works would give a uniform pressure to the consumer, and there would be no necessity for regulating the pressure on the street mains except to reduce an excessive holder pressure. But the loss of pressure in the street mains varies with the rate at which gas is passing through them, being greater at the times of heavy consumption and smaller at times of light consumption. Consequently, if a uniform pressure were maintained at the works, the pressure at which the consumer received the gas would vary between more or less widely separated limits, while, by a proper regulation of the pressure at the works, the gas can be delivered to the majority of the consumers at a pressure that will be fairly uniform throughout the twenty-four hours of each day and from day to day. Besides giving a better service to the consumer the proper regulation of the pressure on the street mains reduces leakage by keeping the mains from being subjected to an excessive pressure during the time of light consumption, as would be the case if a uniform pressure, sufficient to meet the requirements of the time of heavy consumption, were maintained.

217. Give the formula from which to calculate the amount of gas that will be delivered by a pipe under given conditions of length and diameter of pipe, and specific gravity and pressure of gas. State the manner in which the formula was originally deduced.

Ans. The formula for calculating the flow of gas through circular pipes, whose length is more than 400 to 500 times their diameter, or in any case where the figure used for pressure is the difference between initial pressure at one point of the pipe, as, for instance, the outlet of district governor, and final pressure at another point, is, $Q = 1350\, d^2 \sqrt{\frac{pd}{sl}}$ in which

Q=Quantity of gas passing in cubic feet per hour.

d=diameter of pipe in inches.

p=loss of pressure in inches of water, that is, the difference between the pressure at the beginning and that at the end of the line of pipe through which the gas flows.

s=specific gravity of gas, air being taken as 1.000.

l=length of pipe in yards.

The formula is derived from the law of mechanics relating to the flow of fluids through pipes without friction, modified by well established facts as to the laws regulating the friction of fluids upon solids.

For flow without friction the law is that the velocity of such flow is dependent upon the pressure and is the same as would be acquired by a body falling through a height equal to that of a column of the fluid in question that would produce the given pressure. According to this $v^2 = 2g\frac{p}{S}$ or $p = \frac{S}{2g}v^2$ in which v=velocity in feet per second, g=the force of gravity= 32.19, p=pressure in pounds per square foot under which the fluid is supplied to the pipe and S=the weight of a cubic foot of the fluid in pounds.

The facts in regard to the friction of fluids upon solids are as follows :

1. Such friction is independent of the hydrostatic pressure to which the fluid is subjected.

2. It is proportional to the area of the moving surface.

3. It varies with the velocity of the fluid. (While the exact ratio is not known, it is sufficiently accurate for practical purposes to assume that the friction varies as the square of the velocity.)

4. It may also be assumed to be proportional to the weight of the fluid, or its specific gravity.

These seem to be the only conditions affecting the friction provided the fluid be in a state of perfect fluidity and that the surface of the solid be so smooth as not to offer obstructions to the passage of the fluid along it.

The force absorbed by friction according to these rules can be expressed by the equation $f=Ml'cSv^2$ in which M=a constant, called the coefficient of friction, to be determined by experiment, l'=length of pipe and c its circumference, both in feet, S=the weight of a cubic foot of the fluid in pounds and v = the velocity in feet per second. In the case of a pipe whose area equals a, if p' is the added pressure in pounds per square foot, the total force required to overcome friction will be ap', and as it also equals $Ml'cSv^2$ we have $ap' = Ml'cSv^2$ or $p' = Ml'\frac{c}{a}Sv^2$. This pressure must be added to that required to produce a certain velocity without friction if the same velocity is to be maintained against friction. Therefore the total pressure necessary to produce motion and overcome friction will be

$$P=p+p'=\frac{S}{2g}v^2+Ml'\frac{c}{a}Sv^2 \quad \text{or}$$

$$P=\left(\frac{1}{2g}+Ml'\frac{c}{a}\right) Sv^2 \qquad (1)$$

With a circular pipe whose internal diameter is d_1, we have

$c=3.1416d_1$ and $a=\frac{3.1416d_1{}^2}{4}$ or $\frac{c}{a}=\frac{4}{d_1}$ and substituting this and the known value 32.19 for g we have

$$P=Sv^2\left(4M\frac{l'}{d_1}+0.0156\right) \qquad (2)$$

From various measurements of the quantity of fluid flowing from pipes under known conditions the value of M has been determined to be 0.0001 or $\frac{1}{10000}$. Substituting we have

$$P=Sv^2\left(\frac{l'}{2500d_1}+0.0156\right) \qquad (3)$$

For use in problems concerning the flow of illuminating gas this formula can be further modified. The pressure is generally expressed by the height in inches of an equivalent column of water. Representing this by p we have $P=62.5\,\frac{p}{12}=5.2p$. The weight of the gas is also generally expressed in terms of its specific gravity with reference to air. Calling this s then $S=s \times$ weight of a cubic foot of air ($=0.0764$). Substituting these values in equation (3) we have,

$$5.2\,p=v^2\times .0764s\left(\frac{l'}{2500d_1}+0.0156\right)=$$

$$v^2\times s\left(\frac{0.0764l'}{2500d_1}+0.001192\right)\doteq$$

$$v^2\times s\left(\frac{0.0764l'+2.98d_1}{2500d_1}\right) \text{ or}$$

$$v^2=\frac{5.2p}{\frac{s(0.0764l'+2.98d_1)}{2500d_1}}=$$

$\frac{5.2\,p\times 2500d_1}{s(0.0764l'+2.98d_1)}=\frac{13000pd_1}{s(0.0764l'+2.98d_1)}$ and dividing both numerator and denominator of the fraction by 0.0764 we have $v^2=\frac{170157pd_1}{s(l'+39.0d_1)}$ and $v=412.5\sqrt{\frac{pd_1}{s(l'+39.0d_1)}}$ (4)

in which v=velocity of flow in feet per second; p=pressure in inches of water; s=specific gravity of gas with reference to air; l'=length of pipe in feet and d_1=diameter of pipe in feet.

But it is usually desired to know the quantity of gas passed per hour rather than the velocity per second, the diameter of the pipe is usually given in inches and it is more convenient to express the length in yards. Letting $Q =$ quantity in cubic feet per hour, $d =$ diameter in inches and $l =$ length in yards we have,

$$Q = v \times \text{number of seconds in an hour} \times \text{area of pipe} = v \times 3600 \times 0.7854\, d_1^2$$

$$d = 12d_1,\ \text{or}\ d_1 = \frac{d}{12}\ \text{and}\ Q = 3600\, v \times 0.7854 \left(\frac{d}{12}\right)^2 =$$

$$19.63\, d^2 v\ \text{or}\ v = \frac{Q}{19.63d^2}.$$

We also have $l' = 3l$. Now substituting these values for v, d_1 and l' in equation (4) we have,

$$\frac{Q}{19.63d^2} = 412.5 \sqrt{\frac{p\frac{d}{12}}{s\left(3l + 39.0\frac{d}{12}\right)}} \quad \text{or}$$

$$Q = 412.5 \times 19.63d^2 \sqrt{\frac{p\frac{d}{12}}{s\left(3l + 39.0\frac{d}{12}\right)}} =$$

$$412.5 \times 19.63d^2 \sqrt{\frac{\frac{pd}{12}}{\frac{s\,(36l + 39.0d)}{12}}} =$$

$$412.5 \times 19.63d^2 \sqrt{\frac{pd}{s\,(36l + 39.0d)}} =$$

$$412.5 \times 19.63d^2 \sqrt{\frac{1}{36} \times \frac{pd}{s\,(l + 1.08d)}} =$$

$$412.5 \times 19.63d^2 \times \frac{1}{6} \sqrt{\frac{pd}{s\,(l + 1.08d)}} =$$

$$1349.56d^2 \sqrt{\frac{pd}{s\,(l + 1.08d)}} \quad \text{or in round numbers}$$

$$Q = 1350d^2 \sqrt{\frac{pd}{s\,(l + 1.08d)}}$$

The quantity 1.08d is derived from the pressure required to give velocity to the gas as it enters the pipe, and where the pressure is taken after the gas has entered the pipe this must be dropped. In problems where the length of pipe is more than 400 to 500 times its diameter this quantity becomes relatively so small that it may be neglected and the equation taken as $Q = 1350d^2\sqrt{\frac{pd}{sl}}$

In using this formula it must be borne in mind that it is based on the assumption that the pipe is smooth, straight, and horizontal. Any sharp bends or obstructions in the pipe or sudden changes of area will decrease the delivery and therefore it is probable that in most cases this formula will give quantities slightly above the actual delivery for any line of pipe. But used intelligently it enables us to secure a close approximation to the delivery of any proposed line of pipe when the other quantities are known. Any difference in levels must be allowed for, of course. The student is referred to King's Treatise on Coal Gas, Vol. II, Part VIII, Chapter IV (page 374), from which the foregoing has been condensed.

218. If a 4 in. gas main will, under certain conditions of length of main, amount of pressure lost by friction and specific gravity of the gas, deliver 1,000 cubic feet of gas per hour, what amounts of gas will be delivered per hour under the same conditions by a 6 in. main and an 8 in. main respectively?

Ans. The formula by which the amount of gas flowing through pipes under different conditions can be calculated, as given in the answer to question No. 217, is,

$Q = 1350d^2\sqrt{\frac{pd}{sl}} = 1350\sqrt{\frac{d^5p}{sl}}$ in which Q is the number of cubic feet of gas delivered per hour, d is the diameter of the pipe in inches, p is the pressure required for overcoming the friction in the pipe, s is the specific gravity of the gas, and l is the length of pipe in yards. From this formula it will be seen that the amount of gas delivered will, everything else remaining the same, vary as the square root of the fifth power of the diameter of the pipe in inches. The fifth power of 4 is 1,024 and the square root of this is 32; the fifth power of 6 is 7,776 and the square root of this is 88.18, and the fifth power of 8 is 32,768, the square root of which is 181. Therefore, the carrying capacities of 4 in., 6 in. and 8 in. pipes are to each other, all other conditions being the same, as 32 to 88.18 to 181, or as 1 to 2.76 to 5.66. That is, if a 4 in. main will, under certain conditions of length, amount of pressure lost by friction and specific gravity of the gas, deliver 1,000 cubic feet of gas per hour, a 6 in. main will, under the same conditions, deliver 2,760 cubic feet per hour, and an 8 in. main 5,660 cubic feet per hour.

The problem can also be solved with a gas flow computer by setting the figure 4 on the diameter-of-pipe scale opposite the figure 1,000 on the cubic-feet-of-gas-per-hour scale and reading off on this latter scale the figures that stand opposite to 6 and 8 on the diameter-of-pipe scale.

The same relation holds for pipes of any diameters that are to each other in the ratio 4, 6 and 8, or, what is the same thing, the ratio 2, 3 and 4. Thus, a 12 in. pipe will carry 2.76 times and a 16 in. pipe 5.66 times as much gas as an 8 in. pipe.

219. Calculate by means of the ordinary formula for the rate of flow of gas through pipes, the amount of gas that can be delivered per hour through one-half mile of 6 inch pipe with a loss of pressure of $\frac{5}{10}$ inches, the specific gravity of the gas being 0.56.

Ans. The ordinary formula for the rate of flow of gas through a pipe of any size under given conditions of length of pipe, specific gravity of gas and amount of pressure lost in the pipe, as given in the answer to question No. 217, is,

$Q = 1350d^2 \sqrt{\frac{dp}{sl}}$, in which

Q = the volume of gas passed per hour in cubic feet,
d = the diameter of the pipe in inches,
p = the loss of pressure or head in inches of water,
s = the specific gravity of the gas, air being 1.000,

l = the length of the pipe in yards, and

1350 is a constant, the value of which has been determined by experiment.

In the problem given, the value of the different factors are:

$$d = 6 \qquad s = 0.56$$

$$p = \frac{5}{10} \qquad l = 880$$

hence, substituting these values in the formula,

$$Q = 1350 \times 36\sqrt{\frac{6 \times 0.5}{0.56 \times 880}} = 48{,}600\sqrt{\frac{3.0}{492.8}} =$$

$$48{,}600\sqrt{0.00609} = 48{,}600 \times 0.078 = 3{,}790 \text{ cubic feet.}$$

While it is necessary that the student should know the formula for the flow of gas and be able to apply it, in practice the results which have been obtained above by calculation can be obtained much more easily and quickly by the use of a Gas-Flow Computer, which is a device of the slide-rule type by means of which the size of pipe required to deliver any given quantity of gas, or the quantity delivered by a pipe of any size, under any given conditions of length of pipe, loss of pressure and specific gravity of gas can be read off by making the proper adjustments of the various scales marked on the computer. The use of one of these computers enables all problems similar to the one above to be rapidly and quickly solved.

220. It is desired to deliver 9,500 cubic feet of gas per hour through a pipe one mile long with a loss of pressure of 0.5 in. The specific gravity of the gas is 0.55. What size pipe will be required? Give your calculations.

Ans. The answer to question No. 217 gives the formula by which the amount of gas flowing through pipes under different conditions can be calculated. This formula is,

$$Q = 1350\, d^2\sqrt{\frac{dp}{sl}}, \text{ or, as it is also written,}$$

$$Q = 1350\sqrt{\frac{d^5p}{sl}}, \text{ in which}$$

Q = the number of cubic feet of gas delivered per hour,

d = the diameter of the pipe in inches,

p = the pressure, in inches of water, required for overcoming the friction in the pipe,

s = the specific gravity of the gas, air being 1.00, and

l = the length of the pipe in yards.

Squaring both sides of the equation we have,

$$Q^2 = 1350^2 \frac{d^5 p}{sl}$$

Clearing of fractions gives,

$$Q^2 sl = 1350^2 d^5 p,$$

and dividing both sides by $1350^2 p$

$$\frac{Q^2 sl}{1350^2 p} = d^5 \text{ or } d = \sqrt[5]{\frac{Q^2 sl}{1350^2 p}}$$

In the example given

$Q = 9500$

$p = 0.5$

$s = 0.55$ and

$l = 1760$ (1760 yards = 1 mile)

$$\text{so } d^5 = \frac{9500 \times 9500 \times 0.55 \times 1760}{1350 \times 1350 \times 0.5} = \frac{87,362,000,000}{911,250} = 95,870.5 \text{ and } d = \sqrt[5]{95,870.5}.$$

To avoid having to perform the operation of extracting the 5th root the result can be reached by finding from a table of logarithms the logarithm of 95,870.5, dividing this logarithm by 5 and then finding the number for which this quotient is the logarithm. The number so found is the desired 5th root. The logarithm of 95,870.5 is 4.9816850, and this divided by 5 is 0.9963370, the number corresponding to which is 9.916. Therefore, d = 9.916 in. and 10 in. pipe would be required.

Since the pipe chosen will be that of the standard size that is nearest to and larger than the exact size given by the formula, the result can also be reached by trial after finding the value of d^5. In the case in point, since 100,000 is the 5th power of 10 and 59,049 the 5th power of 9, it is evident that the 5th root of 95,870.5 is very near 10, and that therefore 10 in. pipe will be required.

The problem has been worked out above, since it is important to know how to use the formula, but in practice problems of this kind are solved by the use of the Gas-Flow Computer referred to in the answer to question No. 219.

221. The length of a certain run of main is one mile. For the first quarter mile a maximum of 15,000 cubic feet of gas per hour must be carried; from the quarter to the half mile, 12,000 cubic feet per hour must be carried; from the half to the three-quarters, 8,000 cubic feet per hour must be carried, and the amount delivered at the end of the run must be 5,000 cubic feet per hour. The gas has a specific gravity of 0.53; the loss of pressure should be uniform along the line; the total loss should not exceed $\frac{5}{10}$ in., and the pipe rises 60 feet in the mile of run. Calculate the size of pipe required for each section.

Ans. As the pipe rises 60 ft. in the mile of run and the specific gravity of the gas is 0.53, there would be, if the main were delivering no gas at all, a gain of pressure equal to 0.4 in. of water at the delivery end of the pipe (see the answer to question No. 306.) Therefore the effective loss in pressure available for causing the gas to flow through the main will be 0.5 in. + 0.4 in. = 0.9 in., and as the loss is to be uniform throughout the mile, there is an allowable loss of 0.225 in. for each quarter mile.

Applying the formula for the flow of gas in pipes we have for the first section,

$Q = 15,000$ $p = 0.225$
$d = ?$ $s = 0.53$
$l = 440$

Therefore, $15,000 = 1,350\sqrt{\frac{0.225\,d^5}{0.53 \times 440}}$. Dividing both sides of the equation by 150 and performing the multiplication indicated in the denominator of the fraction, this becomes $100 = 9\sqrt{\frac{0.225\,d^5}{233.2}}$. Squaring this we have $10,000 = 81 \times \frac{0.225\,d^5}{233.2}$ from which we obtain $d^5 = \frac{2,332,000}{81 \times 0.225} = \frac{2,332,000}{18.2}$ $= 128,131$ and $d = 10 +$ in.

For the second section,

$$Q = 12{,}000 \qquad p = 0.225$$
$$d = ? \qquad s = 0.53$$
$$l = 440$$

Therefore, $12{,}000 = 1{,}350\sqrt{\frac{0.225\ d^5}{233.2}}$ and reducing $80 = 9\sqrt{\frac{0.225\ d^5}{233.2}}$. Squaring this we have $6{,}400 = 81\frac{0.225\ d^5}{233.2}$ from which we obtain $d^5 = 82{,}004$ and $d = 9 +$ in.

For the third section,

$$Q = 8{,}000 \qquad p = 0.225$$
$$d = ? \qquad s = 0.53$$
$$l = 440$$

Therefore, $8{,}000 = 1{,}350\sqrt{\frac{0.225\ d^5}{233.2}}$ and reducing $160 = 27\sqrt{\frac{0.225\ d^5}{233.2}}$. Squaring this we have $25{,}600 = 729\frac{0.225\ d^5}{233.2}$ from which we obtain $d^5 = 36{,}402$ and $d = 8 +$ in.

For the fourth section,

$$Q = 5{,}000 \qquad p = 0.225$$
$$d = ? \qquad s = 0.53$$
$$l = 440$$

Therefore, $5{,}000 = 1{,}350\sqrt{\frac{0.225\ d^5}{233.2}}$ and reducing $100 = 27\sqrt{\frac{0.225\ d^5}{233.2}}$. Squaring this we have $10{,}000 = 729\frac{0.225\ d^5}{233.2}$ from which we obtain $d^5 = 14{,}219$ and $d = 6 +$ in.

This shows that if it is absolutely necessary to keep the pressure from dropping more than 0.125 in. in each quarter mile, the first section would have to have a diameter larger than 10 in. and the third section a diameter larger than 8 in. In every case the pipe would be made of the standard diameter next above the actual diameter worked out as being necessary. The main would, therefore, be 12 in. for the first quarter mile, 10 in. for the next half mile and 8 in. for the last quarter. If, however, it makes little difference whether or not the drop is perfectly uniform, so long as the total drop allowed on the full length is not exceeded and the variation from uniformity is not great, the first half mile could be made 10 in. and the second half mile 8 in.

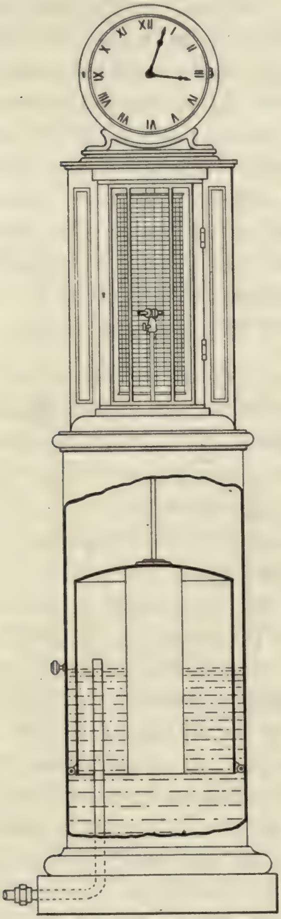
In practice the results which have been obtained above by calculation can be obtained much more easily and quickly by the use of the Gas-Flow Computer, referred to in the answer to question No. 219.

222. Give a description, illustrated with sketches, of some form of recording pressure gauge used for taking street main pressures.

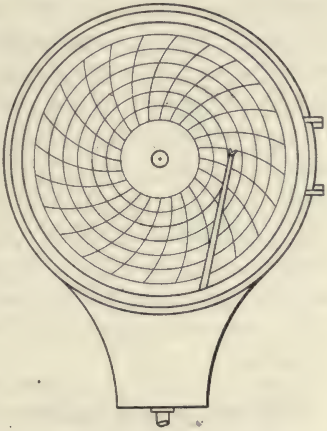
Ans. The form of recording pressure gauge that it is desirable to use for taking street main pressures depends somewhat upon whether these pressures are to be taken at any one location continuously, or for a day or two only. Where pressures are to be taken continuously, as at the gas works or the gas office, it is best to use a gauge which measures the pressure by the height to which a small bell sealed in water is raised by the gas admitted under it, since such gauges are the least subject to get out of order and give inaccurate records. Where pressures are to be taken only for a day or two a year, it is advisable, for the sake of its greater portability, to use a gauge based on the aneroid barometer principle, even though it is necessary to exercise greater care in using it.

A gauge of the first class mentioned, which may be called a "Float Gauge," is shown, partly in elevation and partly in section, on the left half of the accompanying cut. Outwardly it consists of a tinned iron cylindrical case containing the bell and the sealing water, and surmounted by a half cylinder, also of tinned iron, the front of which is closed by a glazed door in the shape of half of a hexagonal prism, which contains the recording apparatus. At the top is a clock by which the recording mechanism is driven.

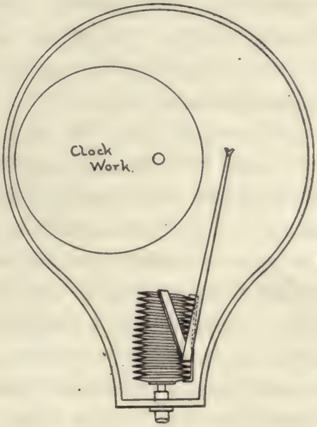
The bell, by the motion of which the pressure is measured, is made of tinned iron, and is provided with a cylindrical float, made concentric with the bell, with such an area that when submerged in water to the full depth of the bell, the weight of the water that it displaces is just equal to that of the bell and its appurtenances, so that when the bell is at the lowest point to which it can sink, it is just afloat when the pressure inside of it is equal to that of the atmosphere, and therefore is ready to rise as soon as the interior pressure exceeds that of the atmosphere. This bell is guided by wheels fastened around its lower edge and working on guides fastened to the case, and by a rod fastened to the centre of



Float Gauge.



Bristol Gauge.



RECORDING PRESSURE GAUGES.

the top and passing up through a small hole in the top of the lower part of the case into the space containing the recording mechanism. Gas from the street main, the pressure in which is to be recorded, is brought under the bell by means of a pipe entering through the base of the case and rising above the water line. A plug with a milled head is placed in the side of the case to drain off any water that may be run in above the water line and there is an outlet at the bottom for running off all the water. An opening, closed with a plug, is provided on the side of the case above the water line for putting in water when necessary. The stop-cock on the gas pipe is usually made with a small side outlet so that when the gas is shut off the interior of the bell is put into communication with the atmosphere through this side opening.

The height to which the bell will rise for each $\frac{1}{10}$ in. gauge pressure possessed by the gas admitted under it, depends upon its weight, its height and the area of the annular space between the circumference of the bell and the float. It is evident that when the total pressure exerted by the gas on the crown of the bell is equal to the weight of the bell and its appurtenances the bell will rise to its full height, since the whole weight will be supported by the gas, and therefore the float, having no weight to carry, will be forced up by the water until its bottom is on the level of the surface of the latter. The total pressure is equal to the gauge pressure of the gas multiplied by the area of the portion of the crown on which the pressure is exerted, and the weight in pounds that will be supported by this pressure is equal to the gauge pressure, in inches of water, multiplied by the area, in square inches, of the portion of the crown on which the pressure is exerted multiplied by 0.036, the weight, in pounds, of a cubic inch of water. Conversely the pressure in inches required to fully raise a bell, the weight and effective area of which is known, is equal to the weight divided by the product of the area and 0.036. In any given case, therefore, knowing the dimensions of the bell and of the float and the total weight, the pressure required to raise the bell to its full height can be calculated, and by dividing the height by the number of tenths of an inch in the pressure so determined, the amount of rise for each $\frac{1}{10}$ in. pressure is obtained. Or, since this rise must be just sufficient to reduce the volume of water displaced by the float by an amount the weight of which is just equal to the total pressure exerted on the top of the bell by a pressure of $\frac{1}{10}$ in. of water, knowing the diameter of the float the rise can be calculated directly by dividing the product of the area, in square inches, of the annular space of the bell and 0.0036 by the product of the area, in square inches, of the float and 0.036, or, what is the same thing, as can be seen by cancelling, by dividing the area, in square inches, of the annular space in the bell by the area of the float multiplied by 10.

The recording mechanism consists of a cylindrical drum supported on a central pivot at the bottom and connected by a central rod at the top to a shaft coming down from the clock. This connection is made in such a way that it can be readily broken and the drum removed. The shaft is so geared to the clockwork that it makes one complete revolution in twenty-four hours, carrying the drum with it when the connection is made. A sheet of paper, ruled with vertical lines to show the time and horizontal lines for the pressure, is wrapped around this drum and fastened so as to be carried around with it as it revolves. A pencil mounted on top of the rod carried by the bell is pressed by a light spring against the paper and makes a continuous line recording the pressure throughout the twenty-four hours. The vertical ruling marking the time is made by dividing the space equal in length to the circumference of the drum into twenty-four equal parts, so that in each hour one of these spaces passes under the pencil point. The proper distance between the horizontal lines marking the pressures is calculated in the manner explained above and the paper ruled accordingly. Both the vertical and horizontal lines are suitably marked to enable the pressure and time corresponding to any point on the sheet to be read off at a glance.

In starting a record the paper must be so placed on the drum, that when the bell is open to atmospheric pressure the pencil point touches the line of zero pressure at the point corresponding to the time at which the start is made.

The Bristol gauge, one of the second class, is illustrated on the right half of the cut. The lower figure shows the pressure indicating mechanism and the upper figure shows a front view of the gauge with the card in place, so that the manner in which this card is ruled can be seen.

Both the indicating and the recording mechanism are contained in one cast iron case, which is a shallow box of an inverted pear-shaped section. The elongated part at the bottom is covered over with a solid cover, while the upper part is provided with a circular, glazed door.

The pressure indicating mechanism, contained in the elongated portion of the case, consists of a number of rings made of thin corrugated brass fastened together so as to form a gas-tight vessel similar to an accordion in shape. The corrugations on each ring are arranged in circles concentric with its edges. The metal being very thin the effect of even a very slight increase in the pressure inside the vessel is to flatten the corrugations, thus increasing the width of the rings and producing an elongation of the vessel. When one side is prevented from lengthening by means of a flexible strip placed against it and fastened to the top and bottom rings by turned-over ends, the effect of the pressure is to cause the vessel to become curved, the top plate being tilted and its centre thrown off the vertical line to the side on which the strip is fastened. The greater the pressure the greater the curvature and the greater the tilting of the top plate and the displacement of its centre from the vertical line. By means of this tilting and displacement, the point of a bent arm attached to the top plate of the vessel is moved, along the arc of a circle, farther away from the vertical line as the pressure increases.

The record of pressures is obtained by providing the point of this arm with means of making a continuous line on a circular card fastened to a plate, which is caused by clockwork to make one revolution in twenty-four hours. The pressure lines are concentric circles placed the proper distance apart, while the lines marking the time are arcs of circles corresponding to the arc along which the marking point travels as the pressure rises and falls. Both sets of lines are so marked as to enable the pressure and time corresponding to any point on the card to be noted at a glance.

Owing to the lightness of its parts a gauge of this kind cannot stand rough usage and must be very carefully handled to prevent its getting out of order and to keep it accurate.

223. How would you proceed to locate an obstruction in the distribution system of your town, the presence of which is indicated by a general complaint of poor supply in a district which is fed from several points and in which the pipes are large enough to properly supply the demand if no obstruction exists?

Ans. It is assumed, as a matter of course, that all the drips in the various mains supplying the district have been gone over, as soon as attention is called to the trouble, to make certain that it does not arise from a flooded drip due to an unusual cause that has developed since the time of the last periodical examination, and that they have been found all right.

This possible cause having been eliminated from the problem, the next step is to determine which of the several feed mains, by which the district is supplied, is the one that is obstructed. To do this it is necessary to observe the pressures, at the time of heavy consumption in the district, at a series of points along each of the mains, using for the purpose lamp post pipes, or special pressure pipes, if either exist, or else the pumping pipes on drips that are suitably located, or as a last resort the consumers' services. If recording gauges are available in sufficient number, they can be used and will give a means of comparing the pressures at the various points during the whole time of heavy consumption; but if they are not available the desired information can be obtained by the use of ordinary syphon gauges in the following manner: Observation must be taken at, at least, two consecutive points simultaneously. The gauge farthest along in the direction in which the work is being done, which should be that in which the gas is expected to flow, is then left in place while the other gauges are moved to the points next in succession and another set of simultaneous observations taken, this process being repeated until the whole length of the pipe has been covered.

When the pressures have to be taken from the services with syphon gauges all the requisite preparatory work should be done in the day-time, so that there will be nothing to do in the evening except to attach the gauges and take the observations. The amount of gas being used through each service, at the time the pressure is observed, should be noted, to determine whether any allowance should be made for a reduction in pressure on this account. Any other causes, such as differences in elevation, that would normally affect the pressure, must also be taken into consideration and an allowance made for their effect.

The location of the points at which the pressures are to be taken will depend largely upon the special conditions existing in any system, but, in the absence of any reason to the contrary, they should be selected so that the pressures should, under normal conditions, show as nearly as possible equal drops between consecutive points.

If no obstruction exists in the main being tested the pressure will show a gradual and uniform decrease at each point, and if the observed pressures decrease in this way the pipe is thus shown to be free from obstruction. An obstruction, by causing the flow of gas through the pipe to be below the normal amount, will cause the pressure to show practically no reduction up to the place at which the obstruction is located, with a sharp drop, equal to almost the whole loss, as soon as the obstruction is passed. When these conditions are observed on one of the mains it is certain, not only that the obstruction that is being sought for is in this main, but also that it is located between the two points showing the large difference in pressure. The exact location can then be found by taking the pressures at various points between those determined as above, the points being taken closer and closer together until the drop in pressure is located between the two consecutive available points that are nearest to each other.

When this has been done, the main must be uncovered at a point midway between those at which the pressures were last taken, a hole tapped in the pipe and the pressure taken to determine on which side of this hole the obstruction is to be sought. A stout wire can then be inserted, in the proper direction, to determine whether the obstruction is within striking distance, and if so, its exact location and nature. If it cannot be located in this way the main must be uncovered at another point, midway between the last point and that one of the points previously taken which shows the marked difference in pressure, a hole tapped, the pressure taken and the wire used, this being repeated until the exact location of the obstruction is found.

The above method, which requires that the taking of pressures be done during the time of maximum consumption, that is usually in the early evening, is the only one that can be employed when the day consumption is comparatively small. When the day consumption is relatively large, the line in which the obstruction exists can be determined in the daytime by bagging off the feed mains, one after another, at points as far removed from the centre of the district as possible, noting, in each case, the pressure at some point in the district, both before and after the bag is put in. If a main is doing its share of the work of supplying the district, stopping it off will cause an appreciable reduction in the pressure, while if it is already obstructed the effect of a complete shutting off will not be marked. If, therefore, the pressure shows no decided change when one of the mains is bagged the obstruction is to be sought in that main, and its position can be located by bagging at several points in succession and noting in each case the drop in pressure on each side of the bag when gas is allowed to escape from the pipe through the bag hole, the bag being put first to one side of the hole and then to the other. As long as the obstruction has not been passed the flow of gas induced in this way will cause only a slight drop on the side towards the feed, and a larger one on the side towards the district. As soon as the pipe is bagged on the district side of the obstruction the drop in pressure will be almost the same on both sides and the obstruction must be looked for between the first hole at which this is observed and the last hole at which normal conditions were found to exist. This method of bagging the mains is especially useful where no services are taken off the feed mains for some distance before the affected district is reached.

The character of the steps to be taken to remove the obstruction will depend upon its nature. If it is an accumulation of water due to a sag in the main, all that is required is the regrading of the main, while if it is a solid obstruction that cannot be removed by the use of solvents, it may be necessary to cut the main before it can be cleared.

224. What should be done to determine each year whether the street mains in a gas company's district are sufficiently large to satisfactorily supply the demand for gas over the whole district?

Ans. The best and surest way in which to ascertain whether or not the street mains of any gas company are large enough to give a satisfactory supply of gas in all parts of its district is to take, and record, each year readings of the pressures existing at a sufficient number of points to thoroughly cover the district, these observations being taken during the hour of heaviest consumption on successive days in the early part of December. If the district is abnormal in not having the heaviest consumption in December, the pressures should be taken during the month in which the largest consumption does occur.

The pressures may be taken either by single readings of a U gauge moved from point to point, or by means of recording gauges provided in sufficient number to allow one to be set at each of the points to be covered by the observations of any one day. The use of recording gauges kept in action for several hours each day gives a means of determining absolutely the lowest pressure existing at any test spot during the hours of heaviest consumption, but it involves a fairly large outlay for gauges and quite a little labor in handling them, while with the U gauge the work can be done at comparatively small expense, provided there are lamp posts connected up to the mains in all parts of the district. If there are no such posts, nor any special pipes arranged so as to be easily accessible on the street, the pressures have to be taken by attaching the gauges to consumers' services at some point between the main and the meter, and it is necessary to use recording gauges.

When the U gauge is used it is essential that the observations made on any one day be taken only during a period when the rate of consumption is practically steady and at its maximum. The length of this period and the time of day at which it occurs can be determined by means of pressure records for the whole twenty-four hours, taken with recording gauges placed for a week at each one of several points carefully selected with a view to obtaining average results for the whole district. The period best suited for taking the observations with the U gauge will be the hour or half-hour during which these records show the lowest pressure, the longer period being taken if there is little variation in the pressure during that length of time, and the shorter one if the pressure does not remain steady during a longer time.

Test points having been selected so as to cover the entire territory from the works to the outskirts in every direction, and the proper time for taking the observations determined, the territory is divided into districts, each of which contains only the number of test points that can be handled during the allotted time. These districts are then covered one after another and as nearly as possible on successive days.

The following description of a system employed where special pressure pipes are installed and recording gauges used is quoted from the answer of a member of the class:

"Pressure tests are made at least once a year of the entire system. In order to do this systematically there have been inserted at all important junctures of the main lines test pipes in the street with iron boxes set over them, similar to drip pipes, so it is convenient to remove a three-quarter inch plug and attach the gauge, a watchman being detailed at each gauge during the time it is set.

"The city is divided into districts which overlap each other to the extent of one or two locations. There are nine gauges set at a time, two of which will be on the same test pipes as were taken the previous day. This is repeated until the whole city has been covered. The lapping of the districts is to make comparisons of successive days as the consumption varies from one day to another.

"These tests are made at the time of maximum consumption, which is considered to be between 5:45 p. m. and 6:00 p. m. during November and December.

"The gauges used are the 'Bristol Recording' type and are set from about 4 p. m. to 8 p. m. each day until the whole city is covered."

225. Is it probable that all of the unaccounted-for gas reported by gas companies represents actual leakage loss from the holders, street mains and services? Give the reasons for your answer.

Ans. It is not probable that all the unaccounted-for gas reported by gas companies is due to actual leakage loss from the holders, street mains and services. In fact, there are many reasons for believing that a large part of the difference between the amount of gas indicated as made by the station meter and that indicated as sold by the consumers' meters is due to a difference between the temperature at which the gas is measured in the station meter and that at which it is measured in the consumers' meters, to inaccuracy of registration in the meters, and, where there are many street lamps, to an actual consumption that is in excess of the amount estimated.

The difference between the temperature at which the gas is measured in the station meter and that at which it is measured in the consumers' meters is an important factor in increasing the amount of unaccounted-for gas, especially if no correction for temperature is applied to the station meter registration. It is now quite customary to keep the temperature of the gas in the purifying boxes comparatively high in order to increase the efficiency of the purifying material, and this leads to the gas being measured in the station meter at a comparatively high temperature, averaging in some cases 70° or over during the whole year. Consumers' meters are, as a rule, set in comparatively cool localities, such as cellars in residences and under show windows in stores, and as the consumption during cold weather is greater than that during warm weather, most of the gas is measured in the consumers' meters at a temperature much below that at which it is measured in the station meter. It is a difficult matter to obtain exact information as to the average temperature at the consumers' meters, but such tests as have been made show that, as a rule, there is enough difference between this temperature and that at the station meter to account for from 3% to 4% of the total make appearing as unaccounted-for gas, even though the registration is perfectly correct in each case.

If there is any error in the registration of the station meter it is apt to be fast, since if this meter is slow the manufacturing results are made to appear poor and the cause is looked up and corrected; while if the meter is fast the manufacturing results are made to appear good, a state of affairs that is very readily accepted as being due to good management. On the other hand, the tendency in the case of the consumers' meters is to register less gas than is actually passed, owing to the stiffening of the diaphragms with age and to the development in the valves of leaks which permit gas used in small quantities, as for hall lights and lights kept burning at night, to pass through the meters without being registered. With a fast station meter and a number of slow consumers' meters the amount of gas unaccounted for may be quite large, even though the actual leakage is small. It is, therefore, important that both the station meter and the consumers' meters be tested at regular intervals so as to insure that they are registering accurately.

Where the street lamp burners are not provided with governors the consumption is very apt to be in excess of that called for by the street lighting contract, which is usually taken as a basis for estimating the amount of gas consumed by the lamps. This is especially the case where there is much difference in level between different parts of the district, or where the street main system is such that it is necessary to have a great difference in pressure over part of the district between the hours of heavy consumption and those of light consumption, since in such cases it is impossible to avoid differences of pressure at the burner during different parts of the night, and it is usually necessary to have the consumption at the time of lowest pressure very nearly, if not fully, equal to the consumption specified in the contract, which makes the consumption during the time of higher pressure larger than is called for.

These points should always be carefully considered and their influence determined as far as possible when dealing with the question of a large amount of unaccounted-for gas. At the same time the influence of the actual loss from the holders and the distribution system should not be neglected.

226. Having taken charge of the engineering work of a gas company showing a large amount of unaccounted-for gas, how would you proceed to determine how much of this was due to actual loss from leaks in the mains and services and how much was due to other causes?

Ans. A large amount of unaccounted-for gas might be due, apart from actual leakage from the mains and services, to inaccurate registration of the amount passing through the station meter, to an excessive difference in the temperatures at which the gas is measured in the station meter and the consumers' meters respectively, to leaks in the holders, or to inaccurate registration by the consumers' meters owing to their being in bad condition. If much gas is used for street lighting, the use in the street lamps of more gas than is charged against them may also be an important factor in increasing the amount of unaccounted-for gas. It is, therefore, necessary to determine the extent to which any or all of the above-named conditions exist before the amount of gas lost by actual leakage from the mains and services can be known.

The first step in the investigation would be to obtain accurate knowledge as to the temperature at which the gas is being measured in the station meter, and to apply the correction for volume necessary to obtain the measurement at the standard temperature suited to the locality. If no records are to be found of a recent reliable test the station meter should also be tested for accuracy of registration.

In the meantime the holders should be examined for leaks, and any that are found should be stopped as far as possible.

The records of the consumers' meters should also be looked up, and if, owing to the absence of any regular system of periodical testing, the majority are found to have been left untested for five years or more, arrangements should be made to bring them in as rapidly as possible for testing and for such repairing as the testing shows to be necessary. At the same time a search should be made for any meters that may be set and using gas without the record of their location showing on the books of the company. This, however, is only necessary when the records are in such poor shape that it seems probable that meters may have been set and not entered on the records, or may have been left out when transferring the records from one book into another.

The character and condition of the street lamp burners should be examined into, as well as the pressure conditions obtaining in the different sections of the town during the hours when the lamps are lighted. If the lamp burners are supposed to be using four or five cubic feet per hour, and the conditions are such that they are actually using eight to ten cubic feet, the extra consumption will materially increase the amount of unaccounted-for gas. This cause is sometimes sufficient to account for an apparent loss of four or five per cent. of the gas made. It can be remedied by the use of either governor burners or checked burners suited to the conditions of pressure under which the gas is to be burned.

If the loss of gas still continues high after all these possible causes of a large amount of unaccounted-for gas have been investigated, and any of them that may have been at work to bring up the amount have been corrected, it will be necessary to charge the loss to actual leaks from the mains and services, and their condition should be examined into without delay.

227. Assuming that you had satisfied yourself that the distributing system of the gas plant under your charge was in bad condition as to leakage, how would you proceed to locate the leaks and put the system in good condition?

Ans. The leaks in a gas distributing system, unprovided with valves or other means of dividing it into sections, that can be isolated and tested for leakage separately, and that is known to be in bad condition, may be located by a general "barring" over the mains without any preliminary division of the system into sections, or else this division may be made, each of the various sections isolated and tested for leakage and the "barring" confined to the sections that are shown by the test to be those in which the leakage is high. The making of tests of the actual leakage by the determination of the amount of gas lost from an isolated section, all the meters on which have been shut off for the time being, is becoming more and more difficult on account of the increasing use of gas for purposes other than that of giving light, which makes the shutting off of all the consumers in a district at any time during the twenty-four hours a cause of inconvenience and complaint. In such case, "barring" may be the only generally practicable method, but the testing by meter of at least such parts of the mains as can be isolated from the others conveniently and cheaply will give a good idea of the average condition of the mains and so help a decision as to the general cause of unaccounted-for gas, and also as to the parts of the system which it will be profitable to bar over and repair.

By "barring" is meant the driving of a pointed steel bar down to the main so that any leaks which may exist on the pipe at or near the points where the bar is used can be detected by the smell of gas that will be found in the holes left when the bar is withdrawn. To give good results, "barring" must be done systematically by a gang of men specially organized for the purpose. This gang should consist of at least five men, one being a caulker, who also acts as foreman, and the others laborers, who for part of the time do the actual "barring," and when leaks are discovered do the digging required to enable them to be gotten at and repaired. In the case of a large system it is advisable to use a larger gang, with a caulker in addition to the foreman and laborers to do the digging, the men assigned to the bars being kept steadily at that work. In the case of the smaller gang the ''barring'' will be kept up until a sufficient number of leaks have been located and then it will be discontinued until all have been dug down to and repaired, while with the large gang the ''barring'' and the digging are carried on simultaneously. Since the majority of the leaks that are not large enough to make themselves apparent without barring occur in the joints, and in many soils the gas from a small leak will not travel through the earth to a distance of more than two or three feet, the bar holes should be made directly over the main and as near a joint as possible. For mains 8 in. and over in diameter it is well to make two holes at each joint, one on each side of the main, as close to it as possible, the bars in this case being driven to the depth of the bottom of the main. This is advisable in order to detect leaks in the bottom of the joint, the gas from which will travel along underneath the main instead of working up around the sides to the top, and which thus would not be detected by a single hole driven down to the top of the main. To secure this result in the absence of detailed street main records showing the locations of the joints, the mains should be uncovered at each street intersection and the joints on the branches located, tested and repaired if found necessary. A line should then be drawn between each two adjacent locations thus found and the bars driven along this line at intervals equal to the distance between the joints. A convenient way of measuring off these intervals is to have a rope about 200 ft. long on which are tied pieces of red tape the proper distance apart. Having located the points, the holes are made by means of a bar of tool steel 1⅛ in. in diameter and about 5 ft. 6 in. long and tapered to a point, the taper extending for about a foot from the end. If the ground is soft, a bar 1 in. in diameter can be used, while if it is very hard on top a short bar about 2 ft. 6 in. long and from 1¼ in. to 1½ in. in diameter should be used to drive through the crust, the hole then being continued to the proper depth with the longer, lighter bar. With the small gang two bars can be used while barring, two men being told off to each bar. These men should be provided with either 6 pound or 8 pound hammers, according to the nature of the soil, with which the bar should be driven until it touches the main. When nearing the main the stroke should be made light, so that there will be no danger of cracking it with the point of the bar. If the bar should happen to be driven into the main, it will be necessary to dig down to the main, tap a hole of a convenient size and put in a plug. The depth at which the main is laid having been ascertained before starting to drive the bar, a mark can be made on the bar at the proper distance from the point, so that it will be known when the danger point is reached and the driving governed accordingly. When the bar is driven down as far as necessary it can be removed by striking each side alternately, to loosen it, and then lifting it, or a wrench may be provided by which the bar can be turned and raised.

After the bar is withdrawn, the foreman should smell at the hole to see if any gas can be noticed. If none is noticed at first the hole should be left open for about ten minutes and then tried again, when if there is still no smell of gas it can be filled up by pouring dirt into it. If there is a leak at the joint or along the pipe near the hole, it will be apparent by the smell of gas remaining noticeable during the whole time that the hole is open. In such a case the point should be marked and dug up in due course. When a hole is opened at a joint in the main the previous measurements should be checked up to see that the holes already made come near the joints, and if it is found that these holes are over 2 ft. away from the joints new holes should be made according to the new measurements.

The nature of the repairs will, of course, depend upon the nature of the leak found. If it is in a lead joint the joint should be re-caulked, and if the lead drives back $\frac{3}{4}$ in. or more a new ring should be put in, or if the gang is equipped with a lead melting pot, the joint should be poured full and again caulked. Before pouring in any new lead the face of the lead already in the joint should be roughened up with a chisel, so that the new and the old lead will be well bound together. No lead joint should ever be pointed up with cement. If the leak is in a cement joint, the joint should be dug out to the first ring of yarn and made over again, using Portland cement and untarred yarn. Where the pipe is under block pavements the holes can be made by removing one stone at the proper point, this stone being set back in place after the hole has been tried and it is found that no leak exists. With asphalt pavements the top of the hole can be filled with Portland cement and smoothed off even with the surface of the pavement.

Records should be made and kept of the size of the main, its distance from the curb and its depth at every point where it is exposed, and these records should also give the locations of every bell exposed in the course of repairs, so that in future it will be easy to see that the holes are driven at the right points to strike the joints. When "barring," the services should be barred over as well as the mains.

If it is decided that it is advisable to district the system and isolate and test each district before barring, this can be done in the following way:

The sections should be so selected as to include the greatest amount of main with the fewest points of supply so as not to have to seal at too many points. The sealing may be done either by means of valves inserted in the mains at the proper points, by means of some of the various isolators on the market, or if the districts are not intended to be permanent, simply by the use of bags. In using bags a good plan is to tap a slightly larger hole than is usual and put two bags into the pipe, one on each side of the hole. The space between the bags is then filled with water which is kept level with the top of a nipple 3 in. long screwed in the hole. If the water runs out of this space very quickly the bags should be removed, the main wiped out with a bunch of waste on a stick and the bags put in again. If they still fail to make a tight joint with the pipe, instead of filling the space between them with plain water, a solution of oatmeal in water, which being thick will not flow through small openings so readily, may be used, or heavy lubricating oil may be poured in ahead of the water to answer the same purpose as the oatmeal. The section being sealed off all the meters in that district should be shut off, using the meter cocks instead of the street service cocks, if these are provided. A test meter should be connected up on a by-pass at the point where the largest supply main for the district is sealed and the amount of gas passing through the meter during fifteen minutes or half an hour noted, the readings of the meter being taken every five minutes to see whether the loss is uniform. Any great variation in the amount passing in different five minutes would indicate that gas was being consumed at some point in the district owing to some of the meters having been overlooked. If the loss is at a uniform rate during the test, a calculation should be made from the results obtained as to the loss per mile of main per year. If this is not more than 50,000 cubic feet per mile of 3 in. main per year the section can be passed for the time being, especially if the mains in it are laid under pavements. If the loss is greater than this, barring should be resorted to until the leaks are found and repaired and the section on the second test shows a leakage at a rate of less than 50,000 cubic feet per mile per year.

228. How would you repair a leak resulting from a broken main? Give a full description of the fittings used and the manner in which these fittings should be applied to the main in order to make the repair complete and permanent.

Ans. The main having been uncovered and the break located, the escape of gas should be stopped temporarily by pressing either clay or soap into the crack. The further procedure depends upon whether the break runs around the pipe so as to be all included within not over four or five inches in length, or extends longitudinally for a greater distance than this. In the first case the repair can be made with a split sleeve; in the second, the cracked piece must be cut out and a new piece inserted.

When a split sleeve is to be used, all dirt and rust must be scraped off the pipe for a distance of a foot on each side of the break, and if the pipe has settled it must be brought back to the proper grade and alignment. A strip of unbleached muslin, wide enough to cover the break with a margin of three or four inches on each side and long enough to wind completely around the pipe several times, is smeared with a putty made of white lead, or equal parts of white and red lead and linseed oil, and wrapped tightly around the pipe over the break. Muslin which has been dipped in, and thoroughly saturated with, melted tallow and then allowed to dry, is also frequently used in a similar manner. This serves to entirely prevent the escape of gas while the job is being completed. A split sleeve, that is, a sleeve made in two pieces, each of them similar in size and shape to the pieces that would be obtained by splitting a solid sleeve along a plane containing both its axis and a diameter and provided with longitudinal flanges by which they can be bolted together, is then applied so as to cover the pipe at the break and for at least three or four inches on each side of it. The joint between the sleeve and the pipe can be satisfactorily made in various ways.

One method is to plaster the inside of each half of the sleeve with a layer of Portland cement, mixed neat, of sufficient thickness to insure the complete filling of the joint and the compacting of the cement without allowing the flanges to come face to face when the two parts are put over the pipe and drawn together by means of the bolts. Enough cement should squeeze out through the spaces between the flanges to fill them thoroughly, but if this does not occur any unfilled places can be pointed up, so that, when the job is completed and the cement has set, the two halves of the sleeve are joined together with a gas-tight joint by the cement between the flanges.

Another method is to make the joints between the flanges gas-tight by using strips of millboard that have been soaked in hot water until they have become soft enough to be squeezed into all the roughnesses of the faces of the flanges when the two halves of the sleeve are put in place, surrounding the pipe, and bolted together. The joint between the sleeve and the pipe is then made exactly as would be done in the case of a solid sleeve, using either lead or cement. The latter is preferable, unless the conditions are very much against its use, since making lead joints involves the carrying to every repair job of a furnace, lead pot and ladle. Drawings of two styles of split sleeves, showing their dimensions and the number of bolts used, can be found in the Proceedings of the American Gas Light Association, Vol. XV, page 88, and on page xiv of the appendix, and also in the American Gas Light Journal, Vol. LXIX, page 712, and Progressive Age, Vol. XVI, page 529.

When the break runs too far along the pipe to be properly covered by a split sleeve, it is necessary to cut out the damaged portion of the pipe, making the cuts at least three or four inches beyond the furthest point reached by the crack at each end, and replace it by a new piece. To do this the main must be uncovered for a sufficient distance to enable bag holes of the proper size to be drilled and tapped far enough apart not to interfere with the work of putting in the new piece. The gas having been shut off, by means of the bags inserted in these holes, the pipe is cut at the proper points, either with a pipe cutter or by the use of diamond points and cold chisels, and a new piece of pipe of the required length cut and put in, a solid sleeve being used to make the joint where the two spigot ends come together. Before sliding the sleeve into place, the opening between the two spigot ends is covered by wrapping the pipe with unbleached muslin prepared and used as is done in connection with the repair by means of a split sleeve. Either lead or cement joints can be made in the bell and in the sleeve, but the use of cement is generally preferable for the reasons stated above.

229. The amount of gas unaccounted for during distribution is expressed sometimes as a percentage of the quantity made and sometimes in terms of the number of thousand cubic feet unaccounted for per mile of main per year. Which method of expression furnishes the best indication of the condition of the distributing system and the best basis for comparison between different companies and different periods in the history of the same company?

Ans. The method of expressing the amount of gas unaccounted for in terms of the number of thousand cubic feet unaccounted for per mile of main per year furnishes a better indication of the condition of the distributing system and a better basis for comparison between different companies and between different periods in the history of the same company than does the expression of this amount as a percentage of the total amount of gas made. The amount of gas sold per mile of main varies so much with different companies that the relation borne by the amount of gas unaccounted for to the total amount made, may be smaller in the case of a company with a compact district than it is in the case of a company with a sparsely settled territory, even though the distribution system of the latter company is in better condition, as shown by the loss of gas per mile of main, than that of the former. Take, for instance, two companies each selling 50,000,000 cubic feet of gas per year, and showing unaccounted-for gas amounting to 5,000,000 cubic feet ; one of which has twenty miles of mains and the other sixty miles, the number of meters in use being approximately the same for the two companies. On a percentage basis the two would show the same figures, 10%, for unaccounted-for gas, but, as a matter of fact, the company that shows a loss of 5,000,000 cubic feet on twenty miles of main, or 250,000 cubic feet per mile of main per year, is not doing as well as the one that only shows a loss of 5,000,000 cubic feet on sixty miles of main, or 83,333 cubic feet per mile per year. The unaccounted-for gas is not made up entirely of gas lost by actual leakage from the mains, being partly due to differences in temperature between the station meter and the consumers' meters and also to inaccuracies of registration on the part of the consumers' meters, but the amount due to these causes would be practically the same in each case, provided the same attention was paid to the testing and repair of the consumers' meters and the maintenance of a proper temperature at the station meter, and the amounts lost by actual leakage would bear to each other very nearly the same proportion as the total amount of the unaccounted-for gas. Therefore, in the instance assumed, the distributing system of the company with sixty miles of mains is really in much better condition than that of the company with twenty miles, although the percentages of gas unaccounted for are the same. To make the comparison perfectly accurate, the lengths of the different sizes of mains should be reduced to the equivalent length of, say, 3 in. main before the division is made.

For comparisons between different periods in the history of the same company, the percentage system is only correct as long as the sales of gas per mile of main remain about the same. When the sales change decidedly, a decrease in the percentage may coincide with an increase in the amount of actual loss. If, for instance, the company with sixty miles of main increased its sales to 100,000,000 cubic feet per year while its main mileage was increased to sixty-five miles, a loss of 8% would amount to 8,000,000 cubic feet per year, equal to 118,000 cubic feet per mile of main, as against a loss of only 83,000 cubic feet when the percentage was 10.

There are, of course, cases where conditions are so different that even the loss per mile of main per year does not afford a basis for accurate comparisons, but, as a general rule, the conditions which affect the accuracy of such a comparison do not vary as much as do those which affect that of the comparison on the percentage basis.

230. What is meant by electrolysis as applied to gas mains and what is its chief cause?

Ans. When applied to gas mains electrolysis is used to denote the corrosion caused by the action of electric currents at the points where these currents leave the gas mains, along which they have previously been traveling, to pass through damp earth to some other conductor that offers a path with a smaller resistance. The process by which the corrosion takes place is exactly similar to what would happen if, in the often-shown experiment of decomposing water by means of electricity, iron plates were substituted for the platinum plates that are used as the poles or electrodes. If this were done the oxygen that gathers around the positive electrode, or anode, would, in combination with the acid in the water, attack the iron and cause it to rust away. This is exactly what happens to the iron of a gas main when an electric current passes from it into damp earth on its way to another conductor. Such earth almost always contains so-called salts, that is, substances formed by the combination of an acid and a base, which are soluble in water, and the current really travels through a solution of these salts. Such a solution is decomposed by the electricity into its acid and basic components, and the acid gathering around the positive electrode, which is the pipe at the place where the current leaves it, attacks the metal. the particles of which are carried with the current through the solution towards the negative electrode. The extent of the corrosion and the rapidity with which it takes place depend upon the amount of moisture in the earth and the quantity of current leaving the pipe. In very dry earth the action is very slow, but in earth that is quite moist it may, when sufficient current passes, proceed very rapidly.

The chief source of the electric currents which travel along the gas mains and leaving them set up electrolytic corrosion at the points of departure, are the return currents of single trolley wire electric railways. These return currents are supposed to travel back through the rails to points near the power house, from which they reach the negative side of the dynamos by means of return conductors bonded to the rails. As a matter of fact, a greater or less quantity of current, the amount depending on the character of the bonding between the separate lengths of rail and the extent to which insulated return conductors are used, leaks into the ground and finds its way to the gas and water pipes, which offer a path of small resistance as long as they run toward the power house. When the vicinity of the power house is reached, or when the pipes turn to go in a direction that takes them farther away from the power house, they no longer offer the path of least resistance, and the current leaves them to go back to the rails or to some other pipe that continues in the proper direction. As stated above, it is at the points where the current thus leaves the pipe that the electrolytic action occurs. The current may also leave the pipe at points where its conductivity is destroyed or reduced by a joint, even if it again returns to the pipe a little farther along, and electrolysis will also take place at such points.

Electrolysis of gas mains cannot be completely prevented as long as the rails are used as return conductors, but the extent to which it occurs can be reduced by careful bonding of the rails, by the provision of insulated return conductors connected to the rails at intervals, and by reducing the conductivity of the gas mains to as low a point as possible so as to make them unattractive as paths for the stray currents.

A committee of the American Gas Light Association made, in 1905, a very complete report upon the causes of electrolysis and the best means of preventing it. This report can be found in the Proceedings of the American Gas Institute, Vol. I, page 761, or in the American Gas Light Journal, Vol. LXXXVI, page 97.

Services.

231. What is the minimum size of pipe which it is considered advisable to use for services for ordinary dwelling houses? Give the reasons for your answer.

Ans. It is not considered good practice to use any pipe smaller than 1 in. for services for ordinary dwelling houses which are within 40 feet of the street main, nor pipe smaller than 1¼ in. when the house is more than 40 feet from the main, and some engineers never use any pipe smaller than 1¼ in. even for shorter services.

The extra cost of the larger pipe is not a large percentage of the total cost of the service, while the use of such pipe provides for a possible increase in the amount of gas required, a provision which is especially necessary at the present time in view of the great development now going on in the sales of gas for fuel purposes. The use of the larger size of pipe also prevents trouble from any slight settlement of the service or from partial stoppage due to any other causes. A small amount of water, naphthalene or other deposit that would hardly be noticed in an 1¼ in. pipe would seriously affect the flow of gas through a ¾ in. pipe, and the extra first cost of the larger pipe is thus often offset by the saving effected by having fewer stopped services to deal with. The extra thickness of the larger pipe also gives it a longer life, especially if the pipe used for services is not coated before being laid. The longer life reduces the cost of service repairs. As will be seen by reference to the pipe cards the difference in thickness between ¾ in. and 1¼ in. pipe is 24 per cent. of the thickness of the smaller pipe.

The use of the larger pipe thus provides against the necessity for enlarging the service when a gas range or water heater is installed, and also reduces the cost of maintenance and renewals.

232. Describe some method of coating wrought iron pipe, such as is used for services, or some other way by which this pipe can be protected from corrosion.

Ans. The method of coating service pipes that seems to have given the best results is that which was first employed in Cincinnati after a series of tests made with a number of different coatings. The specifications for this coating are given, and the manner in which it should be applied to the pipes to give the best results is described, in a "Short Topic" prepared by Mr. A. C. Humphreys for the 1895 meeting of the American Gas Light Association, and published in Vol. XIII of the Proceedings, page 186.

The specifications are as follows: "Bring a kettle of tar (20 gallons) to a low boiling point and add 20 pounds of fresh slaked lime, sifted over the top and worked down. Boil down to a paste or a consistency about midway between tar and pitch. Let it settle for a few minutes, then add 4 pounds of tallow and 1 pound of powdered rosin; stir until they are thoroughly dissolved and incorporated with the tar, then let it cool and settle. Ladle off into barrels. When ready for use, to each barrel of 45 gallons of the above mixture add 4 pounds of crude rubber, dissolved in turpentine to the consistency of thick cream. Heat the mixture to about 100° Fahrenheit, and immerse the service pipe, heated to about the same temperature."

Different methods have been adopted for applying this mixture, the pipes being dipped in some cases and painted in others. Mr. Humphreys said that the best method was to dip the lengths of pipe into the preparation. In this method the mixture is put into a V shaped trough which is long enough to take the longest length of pipe that is apt to be handled. Along the bottom of this trough is run a steam pipe to heat the mixture to the proper temperature. The pieces of pipe to be coated must also be heated, which can be done either by connecting the pieces to a steam pipe and turning steam on them to give them a test for soundness while they are being heated, or by putting them in a long square box with a hinged cover, the interior of the box being kept hot by means of a steam coil run along the bottom. When the pipes are heated to the proper temperature, they are plugged at both ends to prevent any of the coating from getting on the inside, and are dropped into the hot mixture in the trough. After a few minutes they are taken out, placed on a rack over the trough until the excess of the mixture has dropped off, and then transferred to a drying rack in which they are left until the coating has become thoroughly dry and hard. Care must be taken to keep the pieces from touching each other before they are dry, since, if this is not done, they will stick together, and when pulled apart the coating will stick to one pipe and a bare place will be left on the other. Care must also be taken not to get either the mixture or the pipe too hot, since overheating will drive off the more volatile portions of the preparation, and when the coating cools, it will be brittle and liable to chip off. If the proper precautions are taken and fresh portions of the mixture added from time to time to that already in the trough, the coating will be elastic and will cling very tightly to the pipe. The service gang should, however, be supplied with a pot of the preparation, so that after the service is laid, the spots where the coating has been scraped off by the tools can be recoated before filling in the ditch. In some cases the pipe, as it lies in the ditch, is covered for its whole length with an extra layer of the coating, which forms a roof over it.

It will be found rather difficult to dissolve the rubber, but this part of the specifications must not be slighted. Given proper care in the preparation and application of this coating, the pipe covered with it will last much longer than uncoated pipe, and the cost of coating will be more than repaid by the extra life of the services and the lower leakage account.

233. Give a description, illustrated with sketches, of two or more methods of connecting services to street mains, and state what you consider to be the respective advantages and disadvantages of each method.

Ans. Figure 1 shows the swing joint connection and is the method now most widely used. The joint between the street tee and the street ell gives the connection its name and enables the direction of the service pipe to be changed at will during laying, without throwing any strain on the main. This flexibility is especially valuable in congested city streets, where a service has at times but a contracted passage, over some obstructions and under others; or where, for any reason, two parts of a service are joined by a long screw. Not only does the swing joint enable the laying of a service without any strain being left on the main, but also, should pressure be brought to bear on the service at any future time, the joint would be of use in either wholly or in great part taking up the strain.

There are a few engineers who believe that where, as in most large cities, a service seldom rests on undisturbed earth, it is safer to block the pipe at each socket, on both sides of the cock and also close to the main. Of course, this blocking at the main prevents the swing joint from being of use to take up strains coming on the service after it is laid, but the advocates of the blocking believe that a blocked service cannot be pressed down to such an extent as to bring a severe strain on the main, and they desire the blocking under the service at the main, in order to prevent any strain that may come in the direction of the length of the main, due to the fact that the line of the service is offset from the tap hole by the distance from centre of tee to centre of ell.

The use of the tee instead of an ell enables the flow of gas to be stopped while the service is being laid (a tapered rubber plug being made for this purpose), and in case of any stoppage in a service requiring digging at the main, the access to the

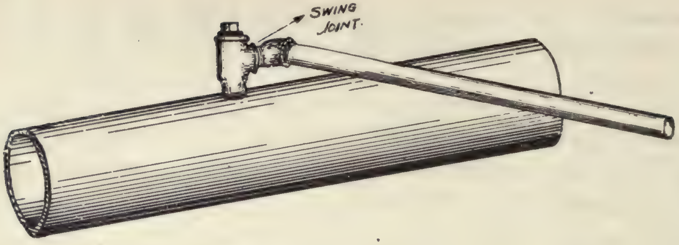


FIG. 1.

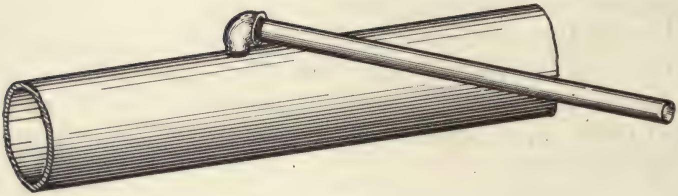


FIG. 2.

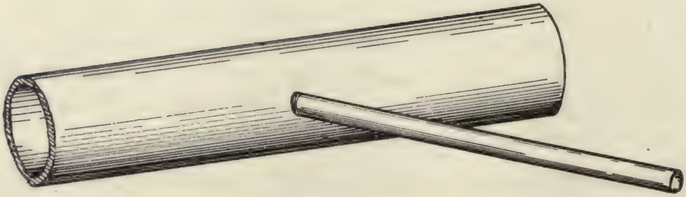


FIG. 3.

service through the top of the tee may obviate any necessity for cutting the service.

The only objection that can be advanced against this form of connection is the greater liability to stoppages as compared with the stiff top connection shown in Figure 2 and the straight side connection shown in Figure 3, Figure 1 having one more bend than Figure 2, and two more than Figure 3. This objection has no force when applied to the large services of the present day and the well purified gas now being sent out, as the cause of the stoppages found in service bends is almost invariably rust and sulphur compounds which stop the comparatively small bore of a ½ in. or ¾ in. pipe. Even naphthalene need not be considered, for it never appears in this country at the junction of main and service.

Figure 2 shows the rigid form of top connection and many thousands of services have been laid in this manner. As has just been said in talking of the swing joint connection, the advantages of simplicity possessed by Figure 2 over Figure 1 are outweighed by the disadvantage of the rigidity of connection, a rigidity which has been the cause of many breaks in 2 in., 3 in. and 4 in. mains.

Figure 3, the straight connection into the side of the main, is the oldest of all forms of connection and was formerly used to a large extent. It allows a wire to be passed through the service into the main itself, quite an advantage when service stoppages were frequent. At present, this advantage of a straight line from house to main is of small importance, while aside from the rigid connection to the main possessed by Figure 3 in common with Figure 2, the growing congestion of city streets makes a side tapped hole more and more an impossibility, because of lack of room to work either a tapping machine or a chisel in a horizontal position.

234. Give a description, illustrated with a sketch, of the making of a 2 in. service connection to a 6 in. main.

Ans. As this question deals only with making the service connection, all reference to digging the hole through different kinds of pavements, and running the service pipe, will be left out.

Assuming a hole dug down to and under the main, with sufficient room for operating the ratchet, and a space under the main for the crow, we must have at hand the following tools and fittings for a 2 in. connection: tapping crow; ratchet; 1½ in. combined tap and drill; diamond point; hammer; monkey-wrench (or Stillson); bar of pliable tough soap; one 1½ in. x 1½ in. x 2 in. street tee; one 2 in. street elbow; one 2 in. plug, and one 1½ in. plug.

The threaded hole in the main into which the first fitting of the service is screwed may be made in two ways.

The older method of proceeding is as follows:

Select the point of tapping, and with the diamond point cut a circular groove slightly smaller than the 1½ in. tap. Cut this so deep that the iron is partly penetrated, stopping the holes, as made, with soft soap. A blow from the hammer will dislodge the central piece, and a piece of soap should at once be placed over the hole, to stop the gas from escaping. Now adjust the crow firmly in place, and set up the tap and ratchet, still leaving soap around the point of the tap and having the slots between the cutting edges full of soap. As most of the cutting has been done with the diamond point, it only remains to complete the drilling and tapping. A little lard oil or engine oil will facilitate tapping, even in cast iron.

At the present time the preliminary cutting out of the hole with a diamond-point chisel has been largely abandoned, the hole being made entirely by drilling, the combined drill and tap being enclosed in a practically gas-tight space, so that no gas escapes while the hole is being drilled and tapped. Several different forms of these tapping machines are on the market.

In both cases proceed as follows after the tapping of the hole is completed:

Leave the tap in the main; remove the crow and unscrew the tap with a wrench, or by reversing the ratchet—holding the spindle in one hand.

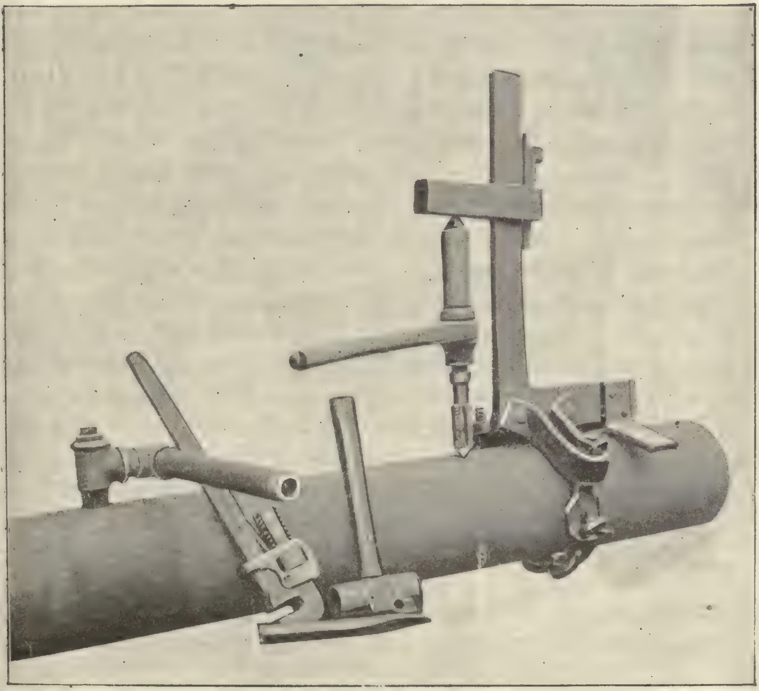
The street tee should have a plug in the top, and a street elbow screwed in the side, it, in turn, to be plugged—all threads wetted with red or white lead or metallic paint. This combination is screwed into the tapped hole, when the tap is withdrawn.

The tee and the elbow should be made up securely, with the elbow pointing horizontally, and at right angles with the main. It is now ready for the service pipe. Soap water should be applied to the fittings to test for leaks, especially leaks through sand holes.

Two men can best adjust the crow, etc., and another man should have his eyes on these two, to render assistance in case of asphyxiation of the men in the hole, through some accident.

A 6-in. pipe should never be tapped with a hole larger than a 1½ in. pipe tap.

See accompanying cut for illustration of tools and procedure used in the older method.

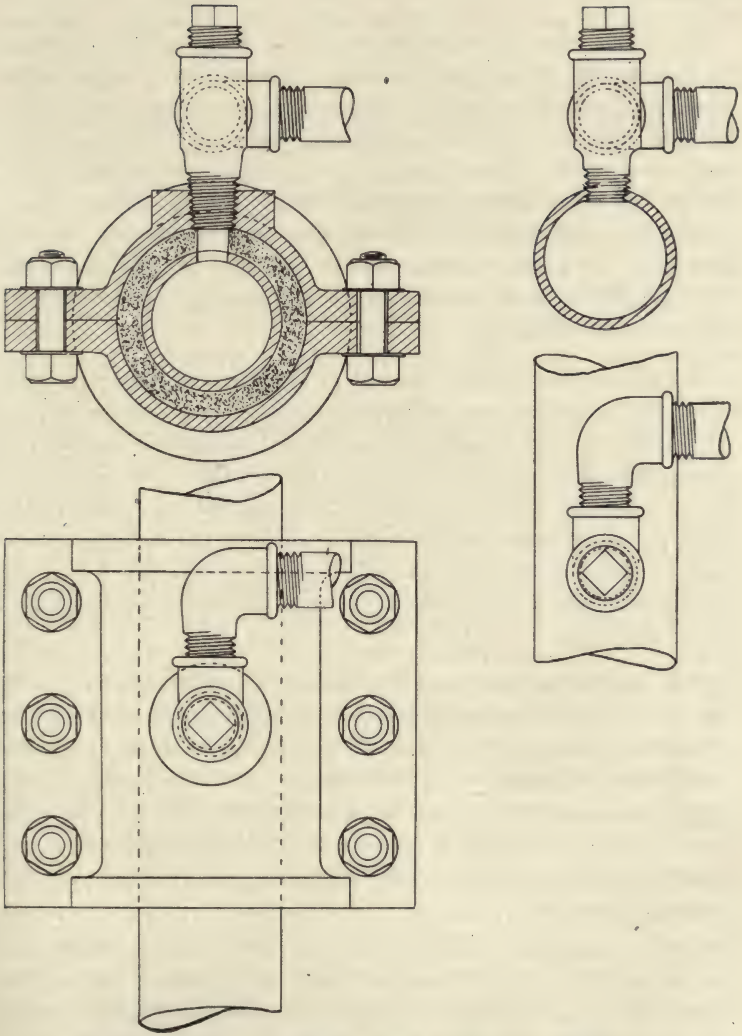


235. Give a description, illustrated with sketches, of the method of connecting a 1 in. service to a 3 in. cast iron main.

Ans. A 1 in. service is very frequently connected into a 3 in. cast iron main by drilling and tapping in the top of the main a hole for ¾ in. pipe, screwing into this a ¾ in. x 1 in. x 1 in. street tee (the ¾ in. thread being the male thread) into the side outlet of which a 1 in. street ell is screwed, the other outlet on the run being plugged, as shown on the cut. This gives a swing joint by which any strain that may result from a settling of the service is taken up without being transmitted to the main. The street tee is used instead of another street ell because it affords an opportunity of shutting off the gas from the men while the service is being run, by inserting a rubber stopper on the end of a rod into the lower or ¾ in. outlet of the tee, and may also prove useful in providing an opening for cleaning purposes in case the service becomes obstructed at any time.

Where the conditions are such as to render it unwise to drill in the main a hole large enough to take ¾ in. pipe, a hole ¾ in. in diameter and untapped can be drilled and a split sleeve tapped for 1 in. pipe put on, the centre of the hole in the sleeve being brought directly over that of the hole in the pipe. This can be done by putting a wooden plug 5 in. or 6 in. long in the hole in the pipe and slipping the hole in the upper half of the sleeve over the end of this plug. The joint between the sleeve and the pipe having been made, the plug is removed and a 1 in. street tee is screwed into the hole in the sleeve, a 1 in. street ell screwed into the side outlet of the tee, and the service run as before. An ordinary split sleeve may be used or a special service sleeve may be made and kept on hand for the purpose. A drawing and a table of dimensions for such sleeves are given in Vol. XV of the Proceedings of the American Gas Light Association, pages xiv and xv, and also in the American Gas Light Journal, Vol. LXIX, page 712, and in Progressive Age, Vol. XVI, page 529.

236. Where existing services have to be connected up to a new main, as is the case when a small main is replaced by a



CONNECTION OF 1 IN. SERVICE TO 3 IN. CAST IRON MAIN.

larger one, how would you make the closing joint between the new and the existing work? Give the reasons for your answer.

Ans. Except in abnormal cases, the final joint to be made in connecting existing service pipes to new mains must be one that can be made without turning either of the runs of the service pipe which are to be connected together. There are various kinds of such joints used with wrought iron or steel pipe, those most commonly employed being unions, either screw or flange, right and left fittings and long screws or running threads. Of these, the last named are best for use under the conditions met with in connecting up existing service pipes to a newly laid main.

Right and left fittings are out of the question entirely apart from the inconvenience of having to carry and use two sets of dies and taps, since their use involves the drawing together of two pieces of pipe that must at the start have been separated by an inch or more of space. This cannot be done in the class of work under consideration without throwing on some part of the service, and probably also on the main, a strain that is too heavy to be borne without an ultimate break and resultant leak.

The same objection holds, although to a less extent, with unions, since it is almost impossible to make the work come so exact that the two faces of the union will press against each other without being drawn up by the screwing of the collar on the nipple. Unions in which the joint is made by a washer are more liable to become leaky than long screws, and ground unions are more expensive and make no better job than long screws.

The long screw is cheap, makes a joint that is as tight and as permanently tight as any of the other joints on the service pipe, and its use enables the connection to be made readily and quickly without throwing any strain on the service or main. It will go together even though the pipe is cut a little short, while as the coupling feeds off of one thread at the same rate that it feeds on the other, the two ends, even if separated by a small space, are not drawn together and no strain is produced when the joint is made up, and this property of enabling the work to be done without causing any strain is not possessed to as great a degree by any other simple and cheap joint.

Consumers' Meters.

237. What are the respective advantages of wet and dry meters for use as consumers' meters?

Ans. The principal advantages of well-made wet meters for use as consumers' meters are the accuracy with which they register the volume of gas passing through them and their simplicity of construction, by reason of which they are able to maintain this accuracy of registration over long periods of time without the necessity of being brought into the shop for repairs.

When made with a compensating device, which will, within limits, automatically keep the water line correct in spite of the evaporation of the water in the body of the meter, and with an anti-tilting valve which will shut off the gas in case an attempt is made to tilt the meter in order to cause it to pass gas without registration, a wet meter will register with great accuracy the gas delivered through it, and as there are no diaphragms or slide valves to get out of order, by drying out or by friction, it does not require the periodical testing that is necessary to make certain that a dry meter is measuring correctly. On the other hand, the wet meter requires more frequent visits by the employees of the gas company, in order to maintain a sufficient quantity of water in the meter, and to see that it is properly leveled.

The great advantage of dry meters as compared with wet meters for use as above is their freedom from the danger of freezing to which meters are liable in cold climates. A second advantage derived from the absence of water is the reduced danger of the collection of water in any trapped places in the house-piping, with the consequent greater freedom from the jumping or complete shutting-off of the lights on the far side of such places.

Other advantages of dry meters are smaller first cost; greater ease of setting on account of their lighter weight, size for size, and of their not requiring to be so accurately leveled ; greater ease of removing on account of their lighter weight, and of the freedom from the difficulty of disposing of the gas-saturated water which is experienced with wet meters ; freedom from risk of the nuisance which may occur through escape of gas, and possibly the spilling of water saturated with gas, when the water in wet meters is replenished, and, consequently, the possibility of being put in places where wet meters would not be wanted by consumers.

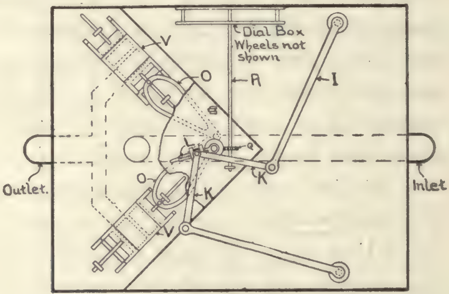
In a general way, the advantage of the wet meter is, that it will, with moderate attention, which does not require the meter's removal from its position, continue for a long space of time, to measure gas accurately ; and the advantages of the dry meter are its cheapness in first cost, its freedom from freezing, and its convenience, in spite of the fact that it requires periodical removal for testing and repairs. The choice between them is determined mainly by comparing the cost of maintaining a high average of accurate registration with the two types. In cold climates, the freezing of the water in wet meters increases so greatly the convenience of dry meters as to make the use of the latter more economical ; but in warm climates, it may easily happen that the use of wet meters will be more economical than that of dry meters.

238. Give a description, illustrated by sketches, of a dry gas meter and explain its action, paying especial attention to the mechanism by which the amount of gas passed by the meter is accurately recorded on the dial.

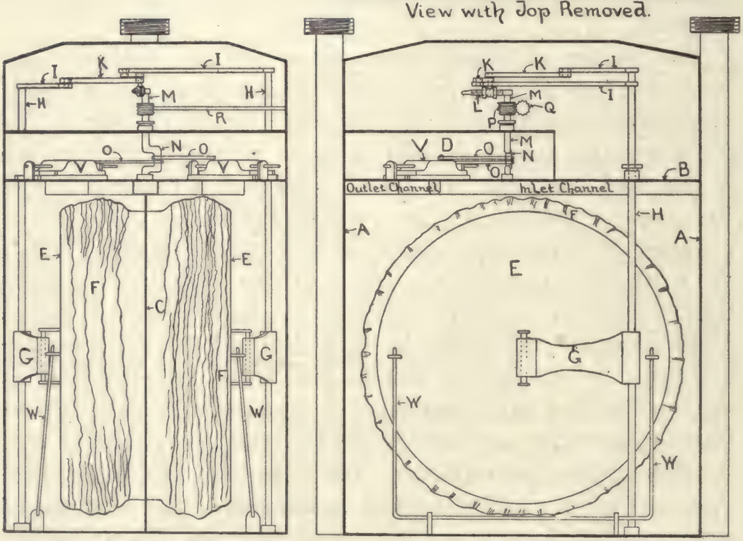
Ans. A dry gas meter consists of a box, usually rectangular in shape and made of tin plate, divided into two main compartments by a horizontal partition. The lower of these compartments is also divided into two equal parts by a vertical partition midway between the front and back of the meter. In the upper compartment there is an enclosed gas-tight chamber.

The measuring apparatus, contained in the two divisions of the lower compartment consists, of a bellows in each division, formed by means of a circular metal disc fastened to one edge of a leather diaphragm, the other edge of which is attached to the central partition, the whole forming a gas-tight space. The alternate opening and closing of these bellows by the pressure of the gas as it is admitted first into the spaces inside and then into the spaces outside of them furnishes motive power which, by suitable mechanism, is made to operate valves to control the flow of gas into and out of the bellows and outer spaces, and also to work the gears which record the amount of gas passed through the meter. The mechanism also controls the extent to which the bellows can open and close, so that a fixed and definite amount of gas passes into and out of the meter each time they are filled and emptied.

The manner in which these operations are performed can be understood by referring to the accompanying cut showing views of the meter with its top and part of the top of the valve chamber removed, with the back removed and with one of the sides removed. In these views A A is the case, B the horizontal partition, C the vertical partition, D the valve chamber, E E the metal discs and F F the diaphragms, which are so attached to the discs and partition that they can only bend outwards. Each of the discs is guided so that it moves along straight lines by the wires W W, and to each is loosely attached one end of an arm G, the other end of which is rigidly fastened to a vertical rod H, resting in a bearing on the bottom of the meter and passing through a stuffing box into the upper compartment. The upper end of each of these vertical rods is rigidly fastened to one end of one of a pair of arms I and K, joined together loosely by a pin. The other end of K is fastened to a pin on a crank arm L working an upright shaft M. This shaft passes through a stuffing box into the valve chamber and is there provided with an eccentric N, from which the valves V V are worked through connecting rods O O. The valves are D valves working on seats containing ports exactly like those in a simple steam engine. In each case the admission port nearest the shaft opens into the space inside the bellows and that farthest from the shaft into the space outside the bellows, while the exhaust port opens into a channel leading to the outlet pipe. A channel from the inlet pipe brings the gas into the valve chamber, which is always filled with gas coming from the service.



View with Top Removed.



View with Side Removed. View with Back Removed.

DRY METER.

The valves are set at such an angle with one another that the supply of gas cannot be cut off from both sides of the meter at the same time and consequently there is no danger of its sticking on a "dead centre."

Starting with the valves in the position shown on the cut the action is as follows, it being assumed that gas is being used: The inside of the bellows in the front compartment and the space outside of the bellows in the back compartment are open to the inlet, while the outside space in front and the inside of the bellows in the back are open to the outlet through the valves and the exhaust port. As gas is being used the pressure on the outlet side is reduced, and the higher pressure in the spaces open to the inlet causes the front bellows to open and the back bellows to close. In moving, the discs E E carry with them the arms G G and a turning motion is thus imparted to the rods H H from which it is transmitted through the arms I I and K K to the crank L and thus to the shaft M and the eccentric N. The rods H H oscillate back and forth through a small arc only, but by means of the arms I I and K K and the crank L this oscillatory motion is transformed into a rotary motion of the shaft M. The turning of the eccentric moves the valves until the conditions of port opening are reversed, first by the front valve and shortly after by the back valve, and the gas then flows into the outside space in front and into the bellows in the back, the front bellows closing and delivering gas while the opening of the back bellows forces gas out of the outer space. A trip catch is provided which trips and allows the crank L to pass over it when this crank is turning in the right direction, but catches and prevents its turning in the wrong direction and thus prevents the meter from running backwards.

It is evident that for each opening and closing of each bellows an amount of gas is displaced which is equal to the volume of the space traversed by the disc, that is, the volume of a cylinder having a base equal to the area of the disc and a height equal to the length of its travel. As the length of travel is kept constant by the controlling mechanism described above, every revolution of the shaft M corresponds to the passage of a fixed, definite amount of gas, and to record the amount of gas passed it is only necessary to record the number of revolutions of this shaft on a dial arranged so as to read, not this number, but the number of feet of gas corresponding to it. To do this a worm wheel P is placed on the shaft M. This worm works a gear wheel Q on a horizontal shaft R, running to the dial of the meter and carrying on its outer end the test hand on this dial. The number of teeth in this gear is so taken that one revolution of it and the shaft will represent either two, five or ten feet, according to the size of the meter. Thus, in a five-light meter, the size of the discs and the length of their travel may be so adjusted that one-sixth of a cubic foot of gas is displaced during a complete cycle of operations, corresponding to one complete revolution of the shaft M. One revolution of the test hand on a meter of this size corresponds to two feet, so the gear wheel P is given twelve teeth and the shaft Q therefore makes one revolution for each twelve revolutions of the shaft M. This shaft Q is the driving shaft of the recording mechanism, and the required rate of revolution of the other hands on the dial is obtained by using the proper chain of gear wheels.

239. What is meant by the term "light" used in designating the size of meters? Is its value the same in small meters, such as 3-lights, as in large meters, such as 100-lights?

Ans. The term "light" used in designating the size of gas meters is a conventional term which is supposed to indicate the number of lights or burners the consumption of which the meter is capable of supplying. It does not, however, afford an exact indication of the amount of gas which may be passed through the meter without overloading it, since its value expressed in the quantity of gas that may be delivered varies very much with the size of the meter. Thus a 3-light meter can easily supply 50 cubic feet per hour, so that in this case the value of a light is nearly 17 cubic feet per hour. A 100-light meter should not be called upon to pass more than 600 cubic feet per hour, which makes the value of the light for this size of meter only 6 cubic feet per hour. The value of a light is therefore not the same in small meters as in large meters.

240. What are the different standard sizes of consumers' meters, and how many cubic feet of gas will each size of meter supply per hour?

Ans. The standard sizes of consumers' meters are,

3 light
5 "
10 "
20 "
30 "
45 "
60 light
80 "
100 "
150 "
200 "
250 "
300 light

The volume of gas that will pass through a meter in a given length of time depends, among other things, upon the pressure lost in the meter, that is, the difference between the pressure of the gas at the inlet and the pressure at the outlet. There is no general agreement as to the amount of pressure that it is permissible to allow the meter to absorb. Mr. C. W. Hinman, in a paper on the "Measurement of Gas," read before the New England Association of Gas Engineers, says that when the meter is measuring gas to be used for illuminating purposes a loss of $\frac{4}{}$ in. is as large as should be permitted, since any larger loss would cause a fluctuation in the pressure at the outlet, due to the working of the meter, of sufficient magnitude to show on the flames. Many engineers set the limit at $\frac{5}{10}$ in., while on the other hand some do not think that the loss should exceed $\frac{3}{10}$ in.

Meters made by different makers differ from each other in the amount of gas passed for the same loss of pressure although rated as being the same size. The figures given in the following table are the average capacities per hour determined from tests of meters of each size from a number of different makers.

Size	Capacity with loss of pressure of $\frac{3}{10}$ in. cu. ft.	Capacity with loss of pressure of $\frac{5}{10}$ in. cu. ft.
3 light	40	55
5 "	50	75
10 "	80	120
20 "	115	160
30 "	175	270
45 "	215	315
60 "	330	475
100 "	385	600
150 "		1015
200 "		1380
300 "		1635

It is generally assumed that it is safe to connect to a meter burners with a greater total capacity than that of the meter, because it is not probable that all the burners will be lighted at any one time, but it is not wise to take too much risk along this line.

241. How would you determine the size of meter that should be set in any given house?

Ans. The size of meter that should be set in any given house depends upon the amount of gas that is apt to be used at any one time, that is, upon the probable maximum rate of consumption. The only way to determine what this rate will be is to count the number of burners and gas-consuming appliances that may be installed in the house. It is usual to assume that every burner will consume five feet per hour. Where there are incandescent burners in use, this will give a liberal margin. The rate of consumption of gas appliances, when not known by previous experience, must either be estimated or actually obtained by setting a meter, lighting all the burners on the appliances and observing the consumption.

After the total number of burners is obtained (the consumption of the appliances in cubic feet being translated into burners by dividing the number of cubic feet per hour by five), the size of meter necessary would be determined by the fitter, either by reference to a schedule furnished by the company giving the sizes of meters corresponding to various numbers of burners, or in the absence of any such schedule, from his knowledge of the capacities of meters in cubic feet per hour. There is considerable uncertainty regarding the capacities of meters, but the following table, based on a loss in pressure between the inlet and outlet of meter of five-tenths of an inch, and upon the smallest types of the various makes of meters, is a good one to use.

CAPACITY OF METERS.

Size	Cubic feet capacity per hour with $\frac{5}{10}$ loss in pressure	Equivalent in 5-foot burners
3	55	11
5	75	15
10	120	24
20	160	32
30	270	54
45	315	63
60	475	95
100	600	120
150	1,015	203
200	1,380	276
300	1,635	327

Knowing the estimated rate of consumption in cubic feet of the house, the fitter need only turn to this capacity table and take that size of meter whose capacity is equal to or greater than the consumption required, if his company believed in setting a meter equal always to the possible maximum consumption in the house. In practice, however, there is seldom a time when all the burners and appliances in the house are used at the same moment, so that it is probably unnecessary to set a meter of the size called for by their united demands, and therefore most schedules for meter sizes are made up on the basis of providing a meter capacity of about two-thirds of the possible maximum demand. The only effect of setting meters according to such a schedule would be that, in the very rare cases where everything was being used at once, the meter would absorb more than five-tenths of an inch pressure.

242. What would be the size and weight of the lead pipe used for making connections for 3-light, 5-light, 10-light and 20-light meters respectively?

Ans. The following sizes of lead pipe should be used for connections for the various sizes of meters covered by the question:

3-light, $\frac{5}{8}$ in.
5-light, $\frac{3}{4}$ in.
10-light, 1 in.
20-light, 1 in.

The weight that should be used will depend upon the amount of care taken in supporting the meters upon shelves. When this is carefully looked after, so that none of the weight of the meters is carried by the connections, good weights are as follows:

⅝ in. pipe for 3-light, . 1½ lb. per foot, known as "C" pipe
¾ in. pipe for 5-light, . 1¾ lb. per foot, known as "C" pipe
1 in. pipe for 10-lt. and 20-lt., 2 lb. per ft., known as "D" pipe

When no particular attention is paid to the support of the meters, so that a large part of their weight is liable to be carried by the connections, it is well to use a heavier pipe and make the weights,

⅝ in. pipe for 3-light, . 2 lb. per foot, known as "B" pipe
¾ in. pipe for 5-light, . 2¼ lb. per foot, known as "B" pipe
1 in. pipe for 10-lt. and 20-lt., 2½ lb. per ft., known as "C" pipe

It is better practice to use good shelves with care in setting the meters upon them properly and the lighter pipe, than to employ the heavier pipe merely to avoid having to exercise such care.

243. In making meter connections the swivel of the meter union is by some inserted in the end of the lead pipe, the axes of the pipe and swivel coinciding, while by others it is inserted in an opening made in the side of the pipe with its axis at right angles to that of the pipe. State, with the reasons for your answer, which method you consider best.

Ans. It is better to insert the swivel in the end of the lead pipe, making what may be called a straight connection, rather than to insert it in an opening cut in the side of the pipe, making a "shoe connection," as it is sometimes called.

The straight connection is much stronger than the "shoe connection." This follows from their respective methods of construction. The swivel when inserted in the end is fastened to the pipe and held by it along a much greater length than when it is inserted through the side, consequently it is held more firmly and is able to stand a greater strain without breaking the joint and causing a leak.

The swivel being simply a continuation of the pipe the straight connection affords a freer passage for the gas. Unless the "shoe connection" is very carefully made the swivel is apt to be pushed so far into the pipe that it seriously obstructs the passage of the gas, even when it is not intentionally pushed far in to secure greater strength. If the hole in the pipe is not cut to the proper size and shape there is also danger of solder running down into the pipe and partially blocking it. The tight fit between the pipe and the swivel in the straight connection prevents any such running down of solder into the pipe. Any obstruction, whether caused by the swivel or by solder, has a tendency to give rise to a deposit of naphthalene in the connection. Even if perfectly made the shoe connection causes the gas to change the direction of its travel very abruptly, and thus throws more pressure than the straight connection, in which the change in direction is never more sudden than that caused by the use of an ell.

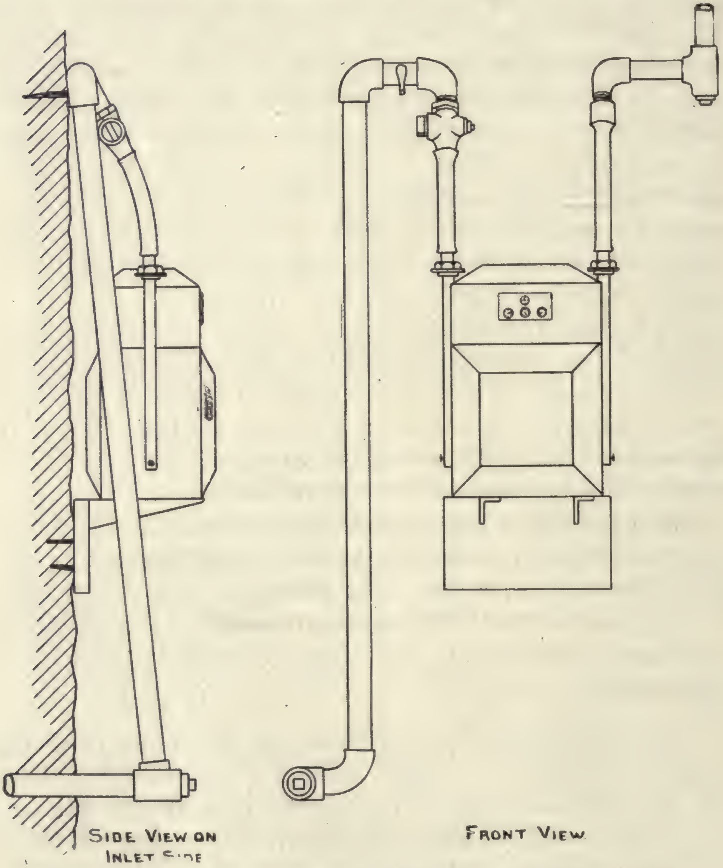
The straight connection requires the use of less labor and material in the making than does the shoe connection, since it is not only easier to expand the end of the pipe for the insertion of the swivel than it is to cut a hole out of its side, but in the shoe connection the end of the pipe must also be closed up and soldered together to insure its tightness.

One claim that is made for the shoe connection is that it is very convenient when meters have to be set close to the ceiling, but even in such cases it is possible to make the connection in other ways that are stronger and more workmanlike, and there is therefore no real reason in favor of this form of connection.

244. Give a description, illustrated by sketches, of the manner in which you would connect a consumer's meter of the ordinary size (three to ten lights) to the end of the service and to the house riser, and also of the manner in which you would support the meter.

Ans. Although some gas companies are adopting all-iron connections even for three, five and ten-light meters, the use of lead connections for meters of these sizes is still so nearly universal that this answer will be confined to the consideration of such connections.

The end of the service coming through the cellar will as finished with a tee set with its side outlet horizontal. Into this outlet is screwed a service elbow and into the elbow a straight piece of pipe of such a length as to bring its upper end the proper distance above the meter inlet when the meter



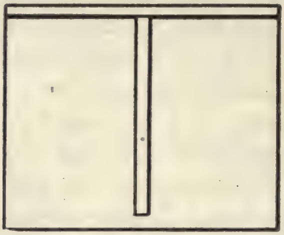
METHOD OF CONNECTING CONSUMER'S METER TO SERVICE AND TO HOUSE RISER.

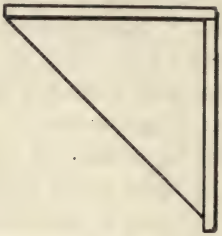
is set at the desired height. On this upper end is put an ordinary elbow in which is inserted a piece of pipe running horizontally and parallel with the cellar wall, and of sufficient length to bring the outlet of a second service elbow, screwed on its end, in line with the meter inlet. The whole combination is then pushed back, turning around the service elbow in the tee at the end of the service as a centre, until the horizontal portion is tight against the cellar wall, to which it is fastened with a pipe hook or hooks, so that it is rigidly held and not liable to be damaged by irresponsible persons even when the meter is disconnected. The meter cock is screwed on the service elbow at the end of the horizontal run, and the connection between it and the meter inlet made by the lead inlet connection, which may either be attached directly to the cock, as in the cut, or be separate from it, according to the kind of meter cock used.

It is necessary to use one more fitting when the connection is made in this way instead of being made, as is usually done, with the outlet of the tee at the end of the service looking vertically upwards and with the pipe running out of this outlet entirely free from the wall, but the security against possible accident when the meter is disconnected, obtained by having the pipe fastened to the wall, is certainly worth the small extra cost.

On the outlet side of the meter the end of the house riser should also be finished off with a tee, out of the side outlet of which a piece of pipe is run to a point on the cellar wall above and behind the meter outlet. On the end of this pipe is screwed a reducing service elbow, to which the lead outlet connection is screwed; or, if the distance between this point and the meter outlet is too great, a reducing elbow is used into which is put a nipple of the proper length, the coupling on the lead outlet connection being screwed on this nipple. On both the inlet and outlet sides of the meter the pipes should be kept the full size of the service and riser respectively until it is necessary to reduce for the meter cock or the outlet connection, as the case may be.

The meter should always be supported on a shelf of some kind so that none of its weight is carried by the connections. The shelf may be made in various ways. A good and simple form is made of three pieces of board, two of which are rectangular and equal in size, while the third is a right angled triangle with its two sides of the same length. These pieces are nailed together to form the shelf in the manner shown on





the sketch. A form of shelf that leaves the bottom of the meter open for inspection is on the market. It consists of a piece of 1 in. board 11½ in. long by 6½ in. wide. At about 3 in. from each end a groove is cut to a depth of about one-half the thickness of the board and running down 2 in. into the board from the top edge. Into these grooves are driven L shaped iron brackets 2 in. deep at the back, tapering to ¼ in. at the front, and 6½ in., 8½ in. and 11½ in. long for three, five and ten light meters respectively. The flat sides of the brackets are uppermost and the meter rests on these, the board being fastened to the wall. This form of shelf is illustrated on the cut showing the meter connections.

When the cellar walls are such that nails cannot be driven into them, or when driven do not obtain a firm hold, holes should be drilled into them with a chisel at the proper points and filled with wooden plugs into which the nails can be driven so as to hold the shelf securely. The same thing can be done for the pipe hooks if they do not get a good hold in the wall.

245. Describe the testing of a consumer's meter, giving all the precautions to be observed to secure accurate results.

Ans. Consumers' meters should be allowed to remain in the same room with the meter-prover at least one hour before testing, to allow the meter to become of the same temperature as the air in the room and the water in the meter-prover. Meters should undergo three distinct tests :

First. Test for registration on a small flame, about the size of a small copper cent ; this is to detect any leakage in the valves, or any holes in the diaphragm. If no registration appears when this test is made, the meter should go to the shop for examination.

Second. Test for irregularity of delivery, to show any stiffness or derangement of the internal mechanism of the meter. To give the test the greatest precision, the meter should be connected to a cluster or line of lights, of or near its full capacity, and if there is any irregularity in the working of the meter, it will show in fluctuation of the flames, and the meter should go to the shop.

Third. If both of the above tests show that the meter is in good working order, the third test should be for accuracy of registration.

When the meter has been connected to the prover, one or more cubic feet of air should be allowed to pass through the meter, to expel the gas remaining after the first two tests, then bring the hand on the prover and the test hand on the meter to zero, open the air passage between the prover and meter and allow the air under the prover-cylinder to pass through the meter, and when the test hand arrives at zero again, the scale on the prover shows to what extent, if any, the meter was in error. If the meter shows 1 per cent. fast or 1½ per cent. slow, it is considered correct, but beyond these limits, it should go to the shop for adjustment or other repair, as examination may dictate.

All meters when not in use should be kept tightly corked, and no meter should be set which has not been tested within thirty days.

246. How often should consumers' meters be tested to ensure their accuracy?

Ans. Opinions differ as to how often consumers' meters of the smaller sizes, that is, up to and including 10-lights, should be tested in order to be certain that they are registering correctly. Some companies plan to bring in and test each year one-third of the total number of these small meters, so that all of them will be brought in for test every three years.

Others lengthen the time out to five years, it being thought that this is a short enough interval if rigidly adhered to. If all meters are tested once in five years the meter registration may be considered accurate.

All meters brought in on account of removal, or any other cause, should also be tested before being sent out again, even though there is no reason to suspect them of incorrectness, and they have already been tested in the regular course.

Large meters, those above 10 lights, should be brought in and tested every year, since owing to the large amounts of gas consumed through these meters any error is of greater consequence than it would be in the smaller meters, and it is profitable to check them up every year.

247. Describe a system of Meter Records by means of which full information in regard to each meter owned by a gas company can be filed so as to be available for ready reference.

Ans. Information in regard to a meter is wanted from various standpoints.

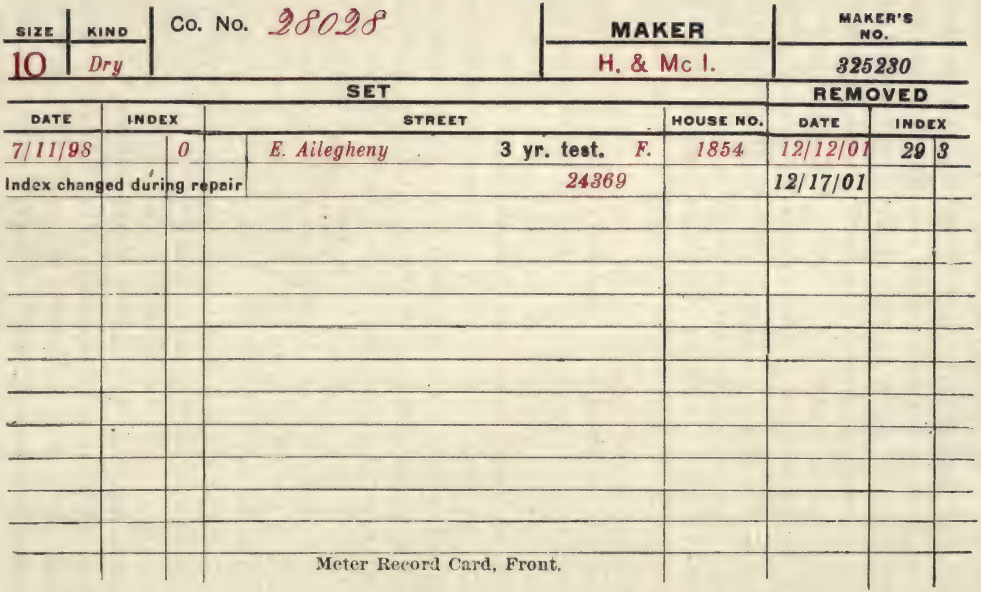
First : There is its physical history as a piece of apparatus, from the time of its purchase to the time of its final disposal by condemnation, including the various kinds of repairs made to it, and its tests for correctness of registration.

Second : There is its location at any given time, whether at a consumer's house, or out of use and undergoing repair, or awaiting setting.

Third : There is the record of the gas passed by it during its various periods of use in consumers' houses.

As the information above noted is always wanted about each meter as a unit (with the exception of the record of tests, as will hereafter be explained), it is absolutely necessary that every meter be designated by a separate number. The meters as purchased contain the maker's name and a serial number of his own. Formerly, this maker's name and number were used to designate the meter in the records of a company, but experience has shown the wisdom of assigning to each meter, as bought, a number known as a "company's number,'' entirely distinct from the maker's number. The company's number is generally on a metal badge, which is soldered to the front of the meter-case on one side of the dial. One of its advantages, especially in a small company, over the maker's number in identifying a meter is enabling numbers of four or not more than five figures to be used in place of the six or seven figures of the maker's series, and the ability to omit altogether the name of the maker on all the various cards on which the meter will figure in its life. Again, in repair work, it is more convenient not to be obliged to replace on any meter the same front (containing the maker's name and number) that may have been taken off, and the use of the company's number (which is soldered to the fixed portion of the case), makes the replacing of the same front a matter of indifference.

At the time the meter is bought and badged, a card known as a ''meter record'' card, and printed like the sample shown, is headed with the number of the meter and filed away in numerical order with other cards of the same kind. Under the conditions obtaining in small companies, all of whose meter setting is done from one shop and whose meter repair work is in the same building as the shop, or in a building adjoining, the presence in the meter record file of a numbered card, filled out with ''Size,'' ''Kind,'' ''Maker'' and ''Maker's Number'' would indicate that the meter in question was in stock. The record of the meter after it leaves the shop is cared for by having all cards for the setting, changing and removing of meters, after the work is done, pass through the hands of the person responsible for the meter record file. The information on these various cards is posted on the proper meter record card, and in this way, knowing a meter number, it is always possible to tell at once its location. For instance, the question arises, ''Where is meter No. 19,454?'' Turning to the meter record card bearing that number, we see that the last entry shows the meter to have been set at 514 North Eleventh Street on December 9, 1903. Again, inquiry is raised as to meter No. 4,241. The meter record card of that number shows that this meter was removed from 210 South Fourteenth Street on May 15, 1903, and this is the last entry on



SIZE	KIND	Co. No. 28028	MAKER	MAKER'S NO.
10	Dry		H. & Mc I.	325230

SET				REMOVED	
DATE	INDEX	STREET	HOUSE NO.	DATE	INDEX
7/11/98	0	E. Allegheny 3 yr. test. F.	1854	12/12/01	29 3
Index changed during repair		24369		12/17/01	

Meter Record Card, Front.

SET					REMOVED		
DATE	INDEX		STREET	HOUSE NO.	DATE	INDEX	

Meter Record Card, Back.

the card. Therefore, this meter will be found either in the stock of meters ready to be sent out, or in the meter repair shop being repaired or awaiting repair.

For recording the various repairs made to a meter during its life, a meter repair card, similar to the sample shown, may be used. These cards, like the meter record cards, are filed by company number. Where a company does its own repairing, as much detail as may be thought advisable in describing the exact nature of repair may be recorded, the idea in such cases being to get as much information as possible, for use in the future, upon the behavior, for instance, of certain oils or certain leathers. Where the repairing is done by a meter company, the information on the nature of repair will probably be limited to the commercial terms for the various kinds of repair. The repair card furnishes a convenient means of determining the actual location of any meter not in use, a record not given by the meter record card, and which is necessary wherever the company is a large one, or where the meter work is done from more than one shop, or the meter repair shop is in another portion of the city from the meter-fitting shops. In such cases, there are three columns ruled on the back of the meter repair card, and headed "Shipped by," "Date" and "Shipped to." All shipments of meters from the district fitting shops to the meter house (stock of meters awaiting repair), from the meter house to the repair shop, from the repair shop to the meter house (stock of repaired meters), and from the meter house to the district fitting shops, are listed on shipping slips and by posting from these slips to the proper meter repair card, the latter will always show the exact location of the meter. To illustrate the working of this record, we will imagine that information is wanted about meter No. 28,028. The proper meter record card shows it was removed from 1854 East Allegheny Avenue, December 17, 1901. Turning to the meter repair card, we trace, by record of shipments, the meter from the district fitting shop to the meter house and through the repair shop, the last entry showing that on November 5, 1902, it was put among the stock of repaired meters. As all meter stocks are piled by

SIZE 10	CO. NO. 28028 MAKER, H. & McI.	
BY WHOM REPAIRED	NATURE OF REPAIR	DATE
	PURCHASED,	APR. '98
X. Y. Co.	3 yr. test. Repairs & 2 New Diaphragms. 1 F. Special Dia.	NOV. '02

Meter Repair Card, Front.

Shipped by		Shipped to	Shipped by		Shipped to
Meter H.	APR. 15 '98	Frankford			
Frankford	DEC. 18 '01	Meter H.			
Meter H.	SEPT. 11 1902	Repair Shop			
Repair Shop	NOV. 5 1902	Meter H.			

Meter Repair Card, Back.

sizes, it would not be a very difficult task to find the meter itself, if it is wanted for any special purpose.

Where, in a large company, the meter repair work is done by a meter company, but for the sake of convenience the meters are all sent from the various fitting shops to one point, from which they are shipped to the meter company, the same shipment record on the back of the meter repair card would trace the meter in every step of its progress, just as it does under the conditions we have already cited.

When a meter is condemned, this fact, with the date, is written on both the meter record and meter repair cards. It is considered advisable to keep all cards representing condemned meters in their proper places, in their respective files, rather than to break the continuity of number by filing the condemned meter cards by themselves. This statement will hold good until the time when, in any series of numbers, the proportion of condemned meters becomes very large as compared with those in use. In such a case, it will probably pay to put the condemned cards by themselves, rather than to have a file, a large proportion of which is composed of inactive cards.

On the sample of the meter record card shown will be noted the index of the meter as set or removed. The opportunity thus afforded of getting on one sheet a continuous record should be taken advantage of for a final check upon the correctness of the meter reading as returned by the men doing the meter work. Every company should have a system by means of which the reading of a meter, as set or removed, is checked several times before the meter card goes from the shop to the office. When, in addition to such checks, the man in charge of the record file is instructed to call attention to any discrepancies which seem indicated by the index record as it comes to him, it will be found that there is little or no chance of any consumer being sent a bill based on errors in reading.

There is nothing inherent in the records kept on the meter record and meter repair cards to prevent these two cards from being combined in one. If such combination were made, the division between the two sets of information might well be a horizontal one, and the card used be about 5 inches by 8 inches. In the case of very large companies, however, it would probably be found more advisable to have separate cards, because of the fact that posting to the two sets of records is done from separate sources, and in actual working it would be found that there would be interference between the clerks engaged in this posting, one being found engaged in posting "record" information in front of the drawers in which were cards needed by another clerk for the posting of "repair" information.

The information thus described as being kept on the meter record card was formerly kept in a book, the "Meter Record Book," and some companies, fearing the loss of a meter card, still prefer the book form.

In addition to the records thus kept of each individual meter, it is important that a record be kept of each proving of a meter as brought in from use, so that, say, a yearly average may be obtained of all such provings, indicating the average amount of correctness of all meters brought in.

248. Describe a method of filing and reporting upon orders for setting and removing meters which makes it certain that all such orders are properly attended to and that the changes of meters made in carrying them out are properly recorded. Include in your answer the system of checks necessary in order that the reading of all meters set and removed may be correctly made and recorded.

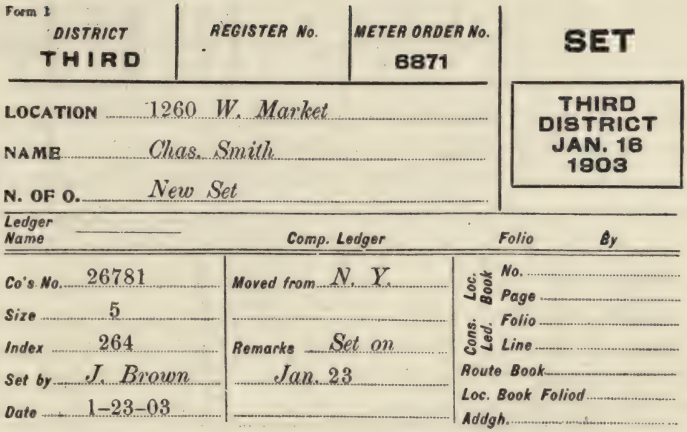
Ans. The system to be described will be applicable to a works of the largest size. Portions of the system may be shortened or altered without impairing its effectiveness.

The orders to set, change, and remove meters are issued by the Commercial Department, that is, the department which keeps the ledgers, collects the bills, etc.

The reasons for such orders are as follows :

1. Set card, when a consumer signs an application for gas.

2. Remove card, when a consumer ceases to use gas and it is the policy of the company to remove the meter, instead of merely shutting it off.



Form 1

DISTRICT **THIRD**	REGISTER No.	METER ORDER No. 6871	**SET**

THIRD
DISTRICT
JAN. 16
1903

LOCATION 1260 W. Market

NAME Chas. Smith

N. OF O. New Set

Ledger Name	Comp. Ledger	Folio	By

Co's No. 26781	Moved from N. Y.	Loc. Book No.
Size 5		Loc. Book Page
Index 264	Remarks Set on	Cons. Led. Folio
Set by J. Brown	Jan. 23	Cons. Led. Line
Date 1-23-03		Route Book
		Loc. Book Foliod
		Addgh.

Form 1

DISTRICT	REGISTER No.	METER ORDER No.
THIRD		8871

LOCATION 1260 W. Market

NAME Chas. Smith

N. OF O. New Set

SET

THIRD
DISTRICT
JAN. 16
1903

DUPLICATE

Original and Duplicate will receive the same "Meter Order Number." Dispatcher will send Original to Shop. This Duplicate will be placed in geographical file of "Duplicate Orders Unattended To"; from which it will be removed when Original Order has been returned from Shop and entered in Meter Location Book This Duplicate will then be placed in serial file, and after accounting to the Superintendent of Meters for orders issued, to be destroyed.

BURNERS IN HOUSE

SIZE SERVICE

REMARKS

REPORT

3. Change card, when the meter in use leaks, registers incorrectly, or is in any other way defective, or when a change in the type or size of the meter is desired. A large number of the change cards would therefore of necessity be originated by the Distribution Department, which attends to the complaints; but they should, in all cases, be issued by the Commercial Department, for reasons which will be explained.

It is absolutely essential that a completed meter card reach the Commercial Department in order that the index may be posted in the consumers' ledger. To insure this, all the cards are issued by that department, and a check held against the order until its completion. To facilitate this, the cards are printed in duplicate as per forms shown.

Considering first the Set Card, Form 1, the Commercial Department, on receiving an application, folds the card at the middle line and inserts a carbon sheet between the original and duplicate. The name and address of the consumer is then written on, and the original and duplicate stamped with the same number, and the two torn apart. The duplicate is filed geographically, and the original sent to the Distribution Department.

In order that the last-named department may keep track of the set card during the execution of the work, the information on it is entered on the History Card, Form 4, bearing the same address as the set card, this history card being one of a complete set of such cards (one for each house, *i. e.*, each system of house piping for which a meter has ever been set) filed geographically. The entry would show that a set card had been issued and was in process of completion for that particular house.

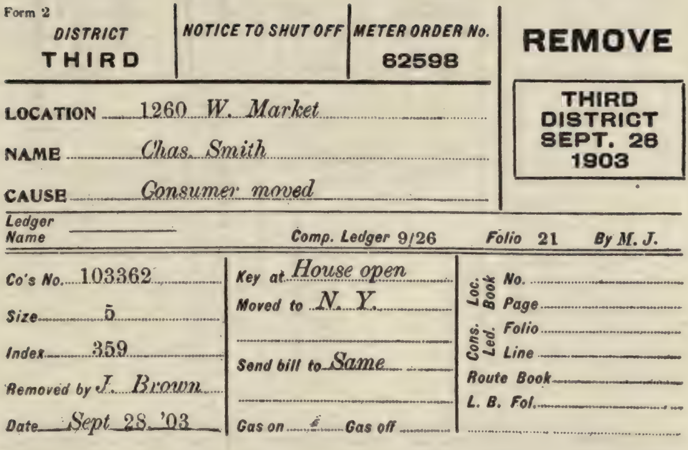
The set card would be handed to a workman to complete, and theoretically both the card and the meter which he would draw from the stock to set, should be charged against him. It has been found in practice, however, that, with an efficient checking system with regard to the card, the charging of the card to the man may be omitted. The meters, however, are charged up by number, index and size on a sheet which is kept in the office. On setting the meter, the workman fills up the blank spaces indicated, giving the meter index and the company's number (the size having been determined and entered in the office), and signs his name, with date. On returning the cards to the shop, the cards and any unused meters returned must balance the meters on the sheet. Any discrepancies would be shown and checked at once.

To check the index of the meter that has been set, the set card is compared with the stock card carried in the district shops of the Distribution Department. This stock card is made out whenever a meter is received in the district shop, either from a consumer by removal, or from the meter repair shop in a consignment of new or repaired meters. It contains simply the Company's number, size and index. To insure its accuracy, it is checked in the following manner: The consignment of meters from the Meter Repair Shop to the district shop is accompanied by a shipping slip, containing the Company's number, size and index. On receipt of the meters the stock card is made from each meter direct. These cards are then compared with the shipping slip, and, as can be readily seen, this double-checks the description of the meter. This stock record is purely a live file, that is, each card represents a meter in stock in the district shop.

When a meter is set the particular card is lifted as described above, and it is perfectly safe to say that if the description on the set card tallies with the description on the stock card, the reading is correct.

In order that a daily record and balance of meters can be kept, each meter set or removed is entered in a Set and Remove Book, which shows the Company's number, size (each in its own column), house number and index. For a meter set, this entry could be made from the meter card, and the stock card compared with the entry. For a meter removed, when the meter is brought in, the stock card is made out from the meter and the entry of the meter in the Set and Remove Book, made directly from the remove card. Comparing the stock card with this entry would then be a thorough check.

Having checked and recorded the index and description, the fact that the set has been completed is entered on the history



Form 2

DISTRICT	NOTICE TO SHUT OFF	METER ORDER No.	
THIRD		62598	**REMOVE**

THIRD
DISTRICT
SEPT. 26
1903

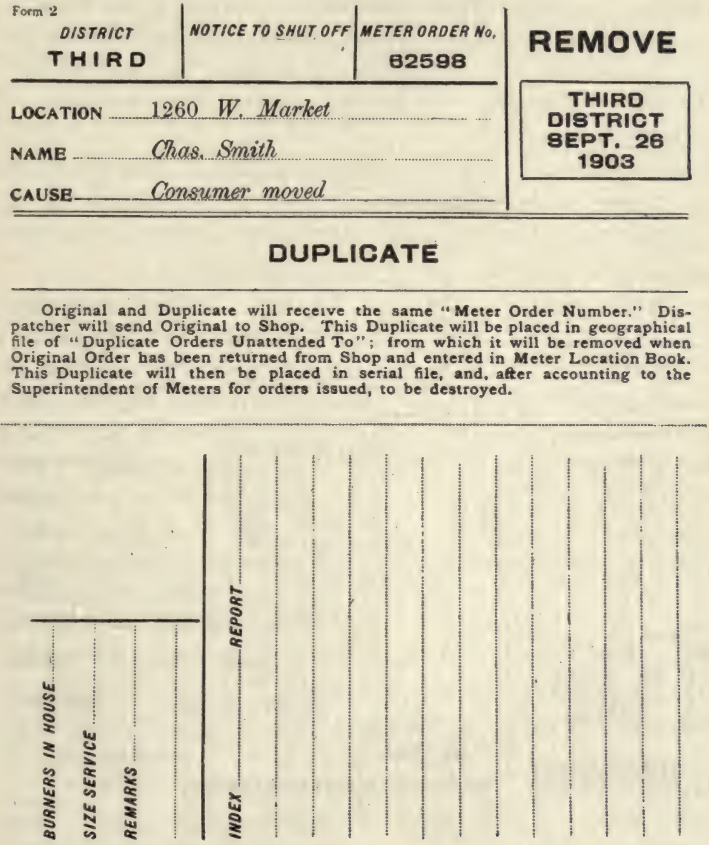
LOCATION 1260 W. Market

NAME Chas. Smith

CAUSE Consumer moved

Ledger Name ______ Comp. Ledger 9/26 Folio 21 By M. J.

Co's No. 103362	Key at House open	Loc. Book No.
Size 5	Moved to N. Y.	Loc. Book Page
Index 359		Cons. Led. Folio
Removed by J. Brown	Send bill to Same	Cons. Led. Line
Date Sept. 28, '03		Route Book
	Gas on ...... Gas off	L. B. Fol.



Form 2

DISTRICT	NOTICE TO SHUT OFF	METER ORDER No.
THIRD		62598

LOCATION 1260 W. Market

NAME Chas. Smith

CAUSE Consumer moved

REMOVE

THIRD
DISTRICT
SEPT. 26
1903

DUPLICATE

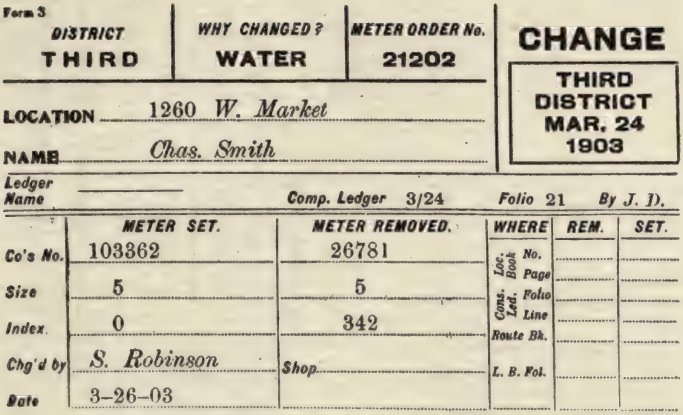
Original and Duplicate will receive the same "Meter Order Number." Dispatcher will send Original to Shop. This Duplicate will be placed in geographical file of "Duplicate Orders Unattended To"; from which it will be removed when Original Order has been returned from Shop and entered in Meter Location Book. This Duplicate will then be placed in serial file, and, after accounting to the Superintendent of Meters for orders issued, to be destroyed.

BURNERS IN HOUSE

SIZE SERVICE

REMARKS

INDEX .... REPORT



Form 3

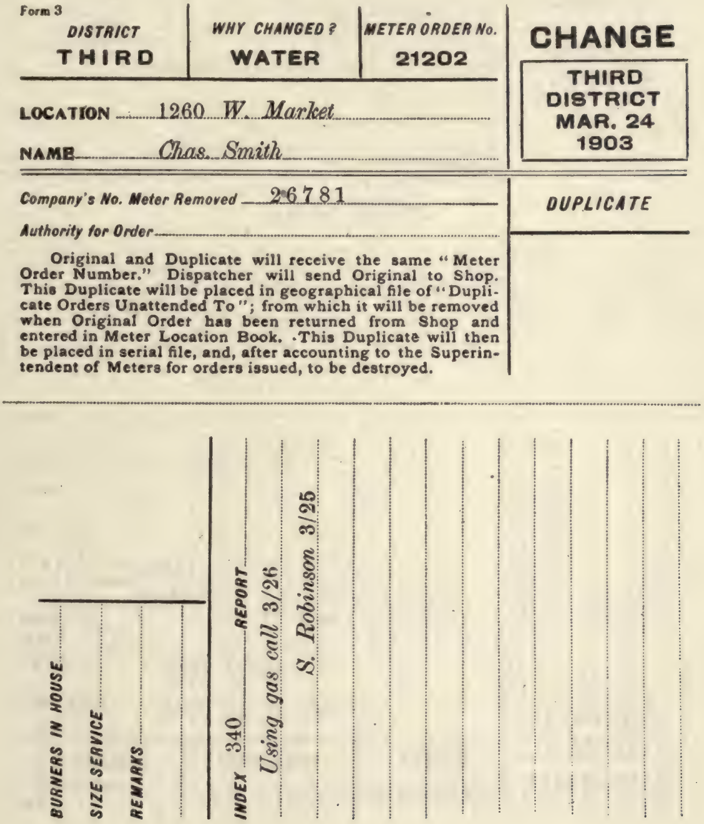
DISTRICT	WHY CHANGED?	METER ORDER No.	CHANGE
THIRD	WATER	21202	THIRD DISTRICT MAR. 24 1903

LOCATION 1260 W. Market

NAME Chas. Smith

Ledger Name ________ Comp. Ledger 3/24 Folio 21 By J. D.

	METER SET.	METER REMOVED.	WHERE	REM.	SET.
Co's No.	103362	26781	Loc. Book No.		
Size	5	5	Loc. Book Page Cons. Led. Folio		
Index	0	342	Cons. Led. Line Route Bk.		
Chg'd by	S. Robinson	Shop	L. B. Fol.		
Date	3-26-03				



Form 3

DISTRICT	WHY CHANGED ?	METER ORDER No.
THIRD	WATER	21202

CHANGE

THIRD
DISTRICT
MAR. 24
1903

LOCATION 1260 W. Market

NAME Chas. Smith

Company's No. Meter Removed 26781

Authority for Order

DUPLICATE

Original and Duplicate will receive the same "Meter Order Number." Dispatcher will send Original to Shop. This Duplicate will be placed in geographical file of "Duplicate Orders Unattended To"; from which it will be removed when Original Ordet has been returned from Shop and entered in Meter Location Book. This Duplicate will then be placed in serial file, and, after accounting to the Superintendent of Meters for orders issued, to be destroyed.

BURNERS IN HOUSE

SIZE SERVICE

REMARKS

INDEX 340 REPORT

Using gas call 3/26

S. Robinson 3/25

FORM 4.

CONSUMER'S RECORD CARD.

1260 *W. Market* ST. *1st Floor*

METER		SET			REMOVED		
CO'S NO.	SIZE	ORDER NO.	DATE	INDEX	ORDER NO.	DATE	INDEX
26781	5	6871	1/23/03	264	21202	3/26	342
103362	5	21202	3/25	0	62598	9/28	359

SERVICE	
SIZE	DATE

House Pipe Inspection	
NO.	DATE
1	
2	
3	

No. of Burners

Stove Line		
SIZE	LENGTH	DATE

ORDER NO.	KIND OF ORDER	DATE REC'D	HISTORY	O. K.
6871	*St.*	1903 1/16	*New Set* ↑ *Set* 5 *lt. meter, first*	
			floor only. *J. Brown* 1/23	*O. K.*
27851	*C*	3/24	*Insufficient* ↑ *Found water in* 5 *lt.*	
			meter, emptied same. Meter should	
			be changed. Ind. 328	
			F. Jenks 3/24	*O. K.*
21202	*Ch*	3/24	*Change water* ↑ *Using gas. Call* 3/26	
			Ind. 340. *S. Robinson* 3/25. *Changed*	
			5 *lt. meter. S. Robinson* 3/26	*O. K.*
62598	*R*	9/26	*Rem. Consumer moved* ↑ *Removed*	
			5 *lt. meter. J. Brown* 9/28	*O. K.*

CONSUMER'S RECORD CARD.

ST.

ORDER NO.	KIND OF ORDER	DATE REC'D	HISTORY	O. K.

card. Form 4 shows the arrangement of the history card. The arrangement of the meter record at the top is self-explanatory. Under "history," the entry of the order number, date received, and "New Set," or "Change Water," or "Remove. Consumer Moved," to the point "A," would be made when the card is first received by the Distribution Department ; the balance when the card is completed. The entry under the O. K. column can be made in red, so that it can be told at a glance whether all orders for the particular house are completed. The system described for the set card applies equally to the remove and to the change card, the latter being a combination of the set and remove.

The full entry on the history card having been made, the card is returned to the Commercial Department. Here the index is entered in the ledgers and the card transmitted to the Meter Repair Shop, where the description is entered on the meter record card described in answer to question No. 247. By keeping the numbers of all meter order cards consecutive, the meter repair shop, by filing the cards numerically, can determine if there are any omissions, and thus any permanent loss of an order card will be known.

The duplicate held in the Commercial Department as a check is destroyed upon the return of the original from the Distribution Department.

It will be noted that Forms 1, 2 and 3 are printed on both sides, the back of the card being used by the fitter to make reports when he is unable to complete the work, or to add any additional information. This will be clear by referring to the reverse side of the change card, these cards being filled out complete, and also entered on the history card. An examination and comparison will render the scheme clear.

The question as to the correct reading of a meter when set or removed often arises after the reading has been changed, either through use or repair of the meter. It is quite important in such cases, involving, as they do, a difference of opinion between the consumer and the company, that the latter has in its possession sufficient evidence to assure the correctness of the reading on its own books. For convenience, the evidence in each case will be shown below, though some of it will be a repetition of what has been written above.

To check the correctness of the reading on a set card, we have,

1. The reading shown on the shipping slip from the meter repair shop, or, if the meter has been proved in the districts, the entry of the index in the proving record book.

2. The entry in the set and remove book.

3. The entry on the history card.

4. If the meter had been previously in use at another location, and removed and proved without altering its index, the removal record could be referred to. The necessity of this would scarcely ever arise.

To check a remove card, we have,

1. The entry of the index in the meter-proving book.

2. The entry in the set and remove book.

3. The entry on the history card.

4. The entry on the shipping slip if the meter is sent away for repairs after removal, or the record of the set, if it did not need repairing and has been again set before the question of error arises.

The change card being a combination of the set and remove, the above applies equally well to it.

House Piping.

249. What are the rules by which to determine the proper size of house piping to be used, when the number of lights to be supplied and the length of pipe along which they are to be placed are known?

Ans. There are several sets of rules in use by gas companies for the determination of the proper sizes for house piping, when the number of lights to be supplied and the length of run are known. The majority of these are copied from the English rules, which are apparently based upon a specific gravity for the gas of 0.420, and a loss of pressure of $\frac{1}{10}$ in. in 30 ft. of piping, and the sizes of pipe determined by them are too small when carburetted water gas, or a mixture of this gas and coal gas, is supplied. In 1897 the American Gas Light Association instructed its Research Committee to prepare a table for house piping based upon a loss of pressure of $\frac{1}{10}$ in. for each 50 ft. of pipe, with gas of a specific gravity of 0.680. This table was reported by the committee and adopted by the Association in 1898, and is given below:

Diameter Inches	Length Feet	Gas per Hour Cubic Feet
$\frac{3}{8}$	20	11
$\frac{1}{2}$	30	22
$\frac{3}{4}$	50	60
1	70	127
$1\frac{1}{4}$	100	222
$1\frac{1}{2}$	150	349
2	200	718
$2\frac{1}{2}$	300	1253
3	450	1977
4	600	4059

No greater length of pipe should be used than is given in the table, *e. g.*, the maximum length of 1 inch pipe allowable under any circumstances is 70 feet, and it should not be expected to carry over 127 cubic feet of gas per hour.

In using this table it is necessary to determine from the number and character of the lights to be supplied the amount of gas which each portion of the house piping system will be required to carry, and, in addition, to obtain from the plans the lengths of these portions. Knowing the quantity of gas and the length of pipe through which it is to be supplied, the table indicates the size of pipe which will pass the required quantity of gas with a loss of pressure equal to or less than $\frac{1}{10}$ in. in fifty feet. The figure for the loss of pressure was adopted after a long discussion as the one which best met all the requirements. The discussion can be found in Vol. XIV of the Proceedings of the American Gas Light Association, pages 122 to 130, immediately following the report of the Research Committee in 1897. An article on the subject, in which a table slightly different from the above is proposed, will be found in the American Gas Light Journal, Vol. LXXVIII, page 162. The article should be read by the students.

250. How often, when, and in what manner would you inspect house piping to insure tightness? Give your reasons.

Ans. When the piping has been completed and before it is covered up by plastering and flooring, for the purpose of seeing that it is of the proper size and so that if any leaks exist they may be discovered while it is comparatively easy to repair them. After the plastering and flooring have been put in, for the purpose of detecting any damage to the pipes that may have been caused by this work. When any additions or alterations have been made, to see whether the new work is tight.

The Sanitary Engineer and Building Record gives the following clear directions :

"If the house is in progress of construction, see that the outlets are all carefully closed with caps, and that the foot of the rising line is stopped. Then at any convenient side light attach the ordinary gas-fitters' pump, which is simply an air pump. To the same side light, or an adjacent one, attach the mercury column gauge used by gas-fitters with a column from fifteen to twenty inches in length. Great care must now be taken to prove that there are no leaks in the gauge or its connection or cock, and in the pump and hose connections, and a good cock should be used between the permanent gas pipe and any temporary connections to pump, so that it may be closed immediately after the pumping stops, to prevent back leakage of air through the pump valves or hose joints.

"When all is complete, pump the pipe system in the house full of air until the mercury rises at least twelve inches. Then close the intermediate cock before mentioned, and should the mercury column be found to 'stand' for five minutes, it is reasonable to assume that the pipes are sufficiently air and gas tight for any pressure they can afterwards be subjected to.

"Should there prove to be a very large leak, it will be apparent at once, as it will be impossible to get a pressure worth considering, the mercury simply bobbing up and down in the tube.

"It may be an outlet that has been neglected to be closed, or it may be a long split in the pipe. If the former, and very close to the pump, the mercury will not respond ; but should it be far away with considerable length of pipe to cause resistance, the mercury will jump and return as suddenly. But should there be a split pipe or an aggregation of small leaks, the mercury will run back steadily, though slower than it rises, between the strokes of the pump. Should it rise well in the glass and sink at the rate of about one inch in five seconds, small leaks only in fittings or joints may then be anticipated. Of course, there are exceptions to these rules, which are only for general guidance.

"To locate a leak, then, that cannot be heard blowing, strong soap water applied with a brush or sponge may be used. The liquid is rubbed over suspected joints or fittings, and air bubbles are blown by the escaping air.

"Sometimes it becomes necessary to use ether in the pipes in locating leaks, if the pipes are under floors or in partitions. The ether is put into a bend of the hose or into a cup attached to the pipe and blown into the pipes with the air. By following the lines of the pipes the approximate position of a leak may be determined by the odor of escaping ether.

"In very large work it is well to prove a floor at a time, and when all are done, connect them with the riser and prove as a whole.

"If the house is an old one, or has been finished, and you have to test for leaks, take off the meter and cap the bottom of the riser; also unhang the gas fixtures and remove the brackets and cap all outlets carefully. Then use ether and locate leaks before tearing up floors or breaking plaster.

"Occasionally, when a gas fitter cannot get a job tight, there is a possibility he may cut off the part or floor of the building he cannot get sufficiently tight to suit the inspector's idea of perfection. The inspector can only prove such practice by removing or slacking off a cap here or there about the house, if he suspect such an attempt. If no air escapes, then he has the dead end."

Whenever a meter is set the piping should be tested by closing all outlets on the piping, and turning gas into the meter. A movement of the test hand indicates a leak.

Burners and Fittings.

251. What is the commonly accepted theory as to the cause of the luminosity of the flame produced by burning illuminating gas in a luminous burner?

Ans. The principal cause of the luminosity of the flames produced by burning illuminating gas in ordinary burners is believed to be the heating to incandescence, before they meet with sufficient air for their combustion, of minute particles of solid carbon formed within the flames. It is thought that these carbon particles are produced by the decomposition of the hydrocarbons in the gas which results from their exposure, while in the interior of the flame and out of contact with air, to the heat produced by the combustion, on the surface of the flame, of the hydrogen, marsh gas and carbon monoxide. As the carbon is set free from chemical combination with another element, or, as it is called, is "nascent" in the flame, the particles are really molecules of carbon many times finer than any particles that can be produced by mechanical subdivision, and therefore are readily heated to incandescence by the heat of the flame and as readily consumed when they come in contact with air.

Under this theory the amount of light given by a flame will depend largely upon the quantity of carbon set free in the flame and upon the temperature to which the particles of carbon are heated before they are consumed. In practice it is found that the greatest illuminating value per cubic foot of gas is given by flames when they are just on the point of smoking, and also that anything which tends to raise the temperature of the flame increases the light given, other things being equal.

It will be noticed that the presence of carbon particles is spoken of as the principal, but not the sole, cause of luminosity in the flames produced by the combustion of illuminating gas. This is because a portion of the light yielded by such flames is derived from the combustion, at the high temperatures existing in them, of marsh gas and of some of the heavier hydrocarbons before they are decomposed. An increase in the temperature of a flame increases the amount of light produced in this way as well as that derived from the incandescence of the carbon particles.

Quite a full discussion of the facts and reasoning upon which the solid particle theory of the luminosity of illuminating gas flames is based will be found in the first of a series of lectures upon Gaseous Illuminants delivered by Prof. V. B. Lewes, and published in the American Gas Light Journal, Vol. LIII, page 877, and in the Journal of Gas Lighting, etc., Vol. LVI, page 1140.

252. Under what conditions must gas be burnt in luminous flame burners to secure the greatest possible yield of light?

Ans. Since the light given by a gas flame is due principally to the raising to incandescence of particles of carbon set free by reactions occurring in the flame, to obtain the maximum amount of light it is necessary that the gas should be so consumed as to secure the setting free in the flame of the greatest possible number of carbon particles, and the raising of these particles to the highest possible temperature before they come into contact with oxygen, and burn. These two conditions can only be secured by the proper regulation of the amount of air supplied to the gas producing the flame, and of the manner in which this air is brought into contact with the gas. The formation of the carbon particles being due to the decomposition of the hydrocarbon constituents of the gas, principally by the effect of heat, anything which tends to cause the combustion of these hydrocarbons before they are sufficiently heated to be decomposed, reduces the amount of light given by the flame by reducing the number of carbon particles present in it. And since the amount of light produced by any given number of carbon particles increases with the temperature to which they are raised, anything that tends to lower the temperature of the flame also reduces the amount of light given by it.

Any admixture or intermingling of air and gas previous to the ignition of the gas reduces the illuminating power, both by partially consuming the hydrocarbons before they are sufficiently heated to be decomposed and so reducing the number of carbon particles in the flame, and also by cooling the flame. Any draft by which an excess of air is brought into contact with the flame so as to be heated by it reduces the illuminating power by cooling the flame. To secure the maximum amount of light from the gas, it is, therefore, necessary that the air should be brought into contact with the gas in just the proper amount required for its complete combustion, and in such a way that the contact takes place only on the surface of the flame. With flat flames the great cause of intermingling of air and gas and of excess rush of air against the surface of the flame is a high velocity of exit of the gas from the burner tip into the atmosphere. This velocity of exit increases rapidly with the pressure at which the gas is supplied to the burner tip. It is therefore essential that the pressure at the tip be low. With an Argand burner this pressure can be reduced to practically nothing, but with flat flame burners a certain amount of pressure is necessary to develop the flame to its proper shape, this being especially the case with union jet (fishtail) burners.

Any swirling motion in the gas also tends to produce an intermingling of gas and air as well as a disagreeable noise, and therefore the arrangement of the burner should be such as to supply the gas to the points of ignition in an even flow, free from eddies or any rotary motion.

To insure that all the gas shall be consumed to the best advantage, it is necessary that the proper proportion between the gas and air supply shall exist over the whole surface of the flame, and, therefore, that the gas shall be supplied in equal quantity at all points of ignition.

The principles governing the efficient combustion of gas for the direct production of light are very fully set forth in part IX, chapter V (volume III, page 115 and seq.) of King's Treatise on Coal Gas, from which the above summary has been taken.

253. What details of construction have been adopted in the manufacture of flat flame burners in order to insure that

the combustion of the gas shall take place as far as possible under the conditions stated in the answer to question No. 252?

Ans. The following details of construction have been adopted to put into effect the principles brought out in the answer to question No. 252. To insure the existence of a low pressure at the burner tip the improved forms of flat flame burners are provided either with some form of governor, which maintains the pressure at the tip constantly at the proper point, no matter how much the pressure on the piping increases, or else with a "check," which is usually a metal, steatite or lava disc inserted in the burner pillar so as to cut off any flow of gas to the tip, except through a hole in the disc, the area of which is smaller than that of the opening in the tip, the relation between the area of the opening in the check and that of the opening in the tip varying with the pressure at which the burner is designed to be used; that is, the higher the pressure the smaller the hole in the check for the same sized tip.

In order to maintain the temperature of the flame at as high a point as possible the burner tip should be made of a non-conducting substance, since if made of metal or any other good conductor of heat, the heat which is absorbed and carried away by the tip reduces the temperature of the flame. In all of the best forms of flat flame burners the tips are now made of either lava, steatite or enamel, all of which are poor conductors of heat.

To produce a steady, even flow of gas without any swirling motion some burners have placed between the check and the tip a screen of fine wire gauze which breaks up any currents, and renders the flow of gas uniform throughout the whole area of the burner pillar, while others depend upon the steadying action produced by the large area of the burner pillar above the check as compared with the area of the opening in the tip.

To secure an equal supply of gas to all parts of the flame, slit (batswing) burners are made with what is called a hollow top, by means of which the slit is kept of the same depth in all parts instead of being much thicker at the top than at the sides, as it would necessarily be if the top of the tip were left solid instead of being hollowed out inside to conform with its shape outside. The effect of extra thickness at any place is that less gas passes through the slit at the thick place, and that consequently the conditions are not the same at all parts of the flame. A further improvement in this direction, introduced in some burners, consists in cutting the slit with a circular saw applied from above the tip and thus making it curved on the bottom instead of flat, as is the case when it is cut by sawing in the ordinary way. With the flat bottom slit some of the gas issues at right angles to the axis of the burner only to be folded back on the upper part of the flame by the upward draft of air caused by the heat of the flame, while with a curved bottom slit this effect is avoided as the gas issues in a direction along which it is free to travel without being turned aside, and the flame is thus kept of more even thickness throughout.

In Sugg's table top burners the effect of the upward rush of air in increasing the thickness of the lower edges of the flame is still further guarded against by forming a circular "table" immediately under the top of the tip, the projection of which deflects the currents of air and prevents them from rising vertically against the flame.

254. Flat flame burners are of two kinds, known respectively as fishtail and batswing burners. Give a description of each kind, and state which will give the greatest amount of light from a given illuminating gas, the gas being consumed under the proper conditions to give the best result in each case.

Ans. Fishtail and batswing burners differ in the form of the tip and of the orifices in the tip from which the gas issues.

In the fishtail burner the top of the tip is usually concave, though in the poorer forms the tip has a flat top. The gas issues from the tip through two circular orifices set opposite each other. The axes of these orifices are set at an angle with each other so that the jets of gas meet, and by the force of their impact are spread out into a sheet of flame in a plane midway between the orifices and at right angles to the line drawn through their centres. The shape of the flame produced by a fishtail burner is affected by the angle between the axes of the orifices through the tip, a very acute angle producing a long and narrow flame which is widened and shortened as the angle is made more and more obtuse. The determination of the angle at which the greatest illuminating power per cubic foot of gas is produced is an important point in the design of a fishtail burner, as is also that of the proper size of orifice, since to secure the maximum results it is necessary to use different angles and sizes of orifice with different qualities of gas.

The tip of the batswing burner has a dome-shape top, varying from a hemisphere, or even a shape approximately $\frac{3}{4}$ of a sphere, to a very flat dome. The gas issues through a single orifice, which is a long narrow slit cut through the top of the dome to its lower edge and at right angles to its base. The gas issues from this slit in a sheet, the thickness of which is varied to suit the quality of the gas to be consumed, being thin for rich gases and thick for poor gases. There is little difference at present between the shape of the flame produced by the fishtail and batswing burners respectively, although as they were first designed the fishtail burner gave a long narrow forked flame and the batswing a short broad flame, whence the names.

Since it is necessary that the two circular jets in which the gas issues from a fishtail burner should come together with considerable velocity if the gas is to be well spread out and a good flame produced, this form of burner requires a higher pressure at the tip than is needed with a batswing burner, and consequently the latter as a rule yields more light per cubic foot of gas than does the former when both are being worked under the proper conditions for the attainment of the best results. The fishtail burner is, however, much less apt to stop up than the batswing, and for this reason is given the preference by most gas companies, if any trouble is experienced from burner stoppages.

255. What is the effect of excessive pressure upon the illuminating power of gas burned in an ordinary flat flame burner, and why does it produce this effect?

Ans. When gas burned in an ordinary flat flame burner issues from the tip at an excessive pressure its illuminating value is reduced much below that which can be obtained when the same quantity of the same gas is consumed at a lower pressure, in fact, with high pressures at the tip the luminosity may be entirely destroyed. This effect is the more marked the thinner the flame. It is due to a more rapid mixing of air and gas in the case of the high pressures owing to the greater suction exerted upon the surrounding air since the gas issues from the tip at higher velocities. This rapidity of mixture acts in two ways in destroying the luminosity of the flame. The first effect is to consume more of the hydrocarbons contained in the gas before they are decomposed by the heat of the flame and thus to prevent the formation of the carbon particles to which luminosity is due. The second effect is to cool the flame by the drawing in of an excess of air and by this cooling to retard the decomposition of the hydrocarbons so that still more of them are consumed before being decomposed, and to reduce the temperature to which such carbon particles as are formed can be heated, and in this way further decrease the amount of light given by the flame. This cooling and diluting effect becomes of greater importance as the pressure increases, until with a sufficiently high pressure the flame is entirely extinguished by the cooling effect of the excess of air drawn in and mixed with the gas.

256. Describe an Argand burner and state how it compares in efficiency from a light-giving standpoint with flat flame burners.

Ans. The Argand burner is a luminous flame burner in which the gas is burned in an annular flame with separate air supplies for the interior and the exterior surfaces of the flame. The flame is surrounded by a glass chimney. The burner tip is in the form of a hollow cylindrical annulus with a round top which is perforated with a number of small circular holes spaced so closely together that the jets of gas issuing from them coalesce into a solid ring of flame. In the best form of Argands this tip is formed of steatite, or some similar substance, which has the advantages over metal of being a non-conductor of heat and of not being subject to corrosion, and therefore allows the attainment of a higher flame temperature and of a longer life for the burner than is possible with a metal tip. In the centre of the interior air opening is placed a narrow metal spike, like a piece of very thick wire, the object of which is to steady the interior air current and give it a direction of travel parallel to that of the gas. The external air supply is divided into two parts by the use of a frustrum of a hollow cone made of metal which surrounds the tip for its full height. The largest portion of the air supply for the exterior surface of the flame comes into the chimney on the inside of this cone, and is directed by it upon the base of the flame, but as the bottom of the cone does not reach quite to the base of the chimney another portion of this air supply enters between the cone and the chimney and ascends next the chimney to supply the upper part of the flame. The gas is supplied to the gas chamber in the tip by three small supply pipes spaced at equal distances around the circle, the combined area of the openings in these pipes being less than that of the opening in the fixture on which the burner is screwed. The number of holes in the tip may be varied, so long as their size is kept such as is suitable to the quality of the gas to be consumed, and their combined area is larger than that of the openings in the pipes through which the gas reaches the tip.

The draft of the chimney used with an Argand burner furnishes a motive force by which the air required for combustion is drawn into the flame and the gas is not required to exert any injector action to accomplish this object, nor is it necessary to have any great velocity of exit from the burner orifice to give the proper shape to the flame. It is therefore possible to have the gas flow from the holes in an Argand burner at practically no pressure, and since the air supply can be very closely regulated by varying the height and size of the chimney used, it is possible to secure very good conditions for luminous combustion in an Argand burner, and consequently these burners give much better illuminating power results from the grades of gas for which they are designed than do the flat flame burners. They are made principally for use with gas with an illuminating value of under 20 candles, and when the gas has a candle power greater than this, the Argands in common use are not fitted for its consumption and do not give any better results than, or even as good results as, good flat flame burners, although if Argand burners were made especially for such gas there is no reason why the results should not be relatively as good as those obtained with the gas of lower grades.

257. State two or more conditions making the use of pressure regulators on house piping, or of governor burners, of advantage.

Ans. First. A wide variation in the pressure at the meter, such as will be found on feed mains running from the works, or holder stations, to different parts of the district supplied. This variation is due to the necessity of carrying on these mains a much higher pressure, at the times of maximum demand, than is required at the times of smaller demand, in order to keep up the pressure at far-away points.

Second. A pressure at the burner higher than is consistent with the economical use of gas, such as will be found at the higher points of very hilly districts.

Where these conditions exist, and especially where the one first mentioned is found, it is very difficult to get satisfactory results from gas burners, particularly if they are incandescent burners, without the use of a pressure regulator at the outlet of the meter or of governors on the burners.

258. What is meant by the expression "an atmospheric (Bunsen) flame"?

Ans. An atmospheric or Bunsen flame is the non-luminous and blue flame produced by the combustion of gas which has been mixed with air previous to its combustion.

259. What is a Bunsen or atmospheric burner?

Ans. A Bunsen or atmospheric burner is a burner arranged so as to mix air with the gas before ignition takes place. The mixture of air and gas is effected in a mixing tube, or chamber, into which the gas enters through a comparatively small opening, the jet so produced acting in a manner similar to the steam jet in an injector, and drawing in air through openings provided for this purpose. The mixture thus made is ignited at the end of the tube and burns with a non-luminous flame. Bunsen burners are principally used for heating purposes and in connection with incandescent gas lighting.

260. Why is the flame of a Bunsen or atmospheric burner non-luminous?

Ans. The flame of a Bunsen or atmospheric burner is non-luminous because such a flame contains none of the carbon particles, the raising of which to incandescence furnishes the greater part of the light produced by a luminous flame, as is explained in the answer to question No. 251. This absence of carbon particles from the atmospheric flame is considered to be due to the chemical activity of the oxygen mixed with the gas before combustion in burning up the hydrocarbons before they can be decomposed; to the diluting effect of the nitrogen which raises the temperature that must be reached before the hydrocarbons decompose; and also to the cooling effect of the air which acts in the same way as the diluting effect and adds to the general result, although when the proportion of air to gas is high, above 3 to 1, the cooling is less than the increase in temperature due to more rapid oxidation. "In an ordinary atmospheric flame the nitrogen and oxygen are of about equal importance in bringing about the loss of luminosity, but if the quantity of air be increased the oxidation becomes the principal factor and the nitrogen practically ceases to exert any influence."

261. What causes an atmospheric burner to "light back," and to what is due the odor given off when this occurs?

Ans. An atmospheric burner "lights back" whenever the speed with which the mixture of air and gas travels through the tube is slower than that at which a flame can spread through the mixture. Anything which decreases the rate of flow of the mixture of air and gas, or which increases the speed at which the flame can spread, will, therefore, tend to produce lighting back.

Some of the causes of a slow speed of the air and gas mixture are a large tube area, the issuing of the gas from the gas orifice at a low velocity because of being under a low pressure, and any draught or concussion of the air that creates a pressure at the point of ignition. The rapidity with which the flame can be propagated back through the mixture depends upon the proportion in which air and gas are present, being greater the more nearly the amount of air present approaches to that required for the complete combustion of the gas. Lighting back may therefore be brought about by the gas being at too low a pressure, by a draught, or a sudden wave of air, such as that produced by the violent closing of a door, or by poor design in the burner, either in the way of providing too large a tube or of permitting the drawing in of too much air for the amount of gas used.

When lighting back occurs the gas burns as it issues from the gas orifice without being previously mixed with air and consequently a luminous flame is produced. The conditions under which this flame burns are extremely unfavorable for the attainment of the complete combustion of the gas, because, not only is the access of air to the flame extremely restricted, but the flame is also surrounded by cold surfaces, and is extinguished by contact with them before complete combustion can take place. The combustion has, however, proceeded to a point at which the decomposition of the hydrocarbons has begun, and as one of the first steps in this decomposition is the formation of acetylene, C_2H_2, the products of the arrested combustion contain an appreciable percentage of acetylene, and it is to this gas that is due the distinctive odor noticed whenever an atmospheric flame is allowed to burn after having lighted back. The products of this arrested combustion also contain carbon monoxide and are therefore poisonous.

262. Why are Bunsen or atmospheric burners used in gas cooking stoves and incandescent gas lights? Why are they not used in the ordinary cylindrical gas heating stoves and gas radiators?

Ans. Atmospheric burners are used in gas cooking stoves principally because the flames from such burners will not deposit soot upon the bottom of the cooking utensils when these utensils come into contact with the flame, as may frequently happen. Any such contact between the bottom of a comparatively cold kettle or pot and a luminous flame will result in the setting free of a quantity of carbon in the form of soot, of which part will stick to the pot and part go off as smoke. Even if actual contact does not take place, the supply of air may become deficient when the top of the stove is covered with pots, and in this case, also, the luminous flame would smoke. As the flame of the atmospheric burner does not need to draw as much oxygen from the atmosphere at the point of ignition as the luminous flame (since from one-third to one-half of the total amount required is already mixed with the gas) the combustion is more apt to be complete under such conditions, while even if it is incomplete no smoke will be given off from the flame.

The same reason holds for the use of the atmospheric burner for heating the mantles of incandescent gas lights. According to Prof. Lewes, carbon is deposited upon these mantles when the volume of air mixed with a 16-candle coal gas is less than 2.2 times that of the gas. This ratio varies, of course, with the quality and character of the gas.

In the ordinary cylindrical heating stoves and gas radiators there is no danger of contact between the flames and any cold surfaces, and the air supply can always be satisfactorily arranged so as to produce complete combustion of the gas. There is, therefore, no danger of the formation of smoke from the luminous flame, and no choice between the luminous flame burner and the atmospheric burner on this ground.

The amount of heat produced by the consumption of equal amounts of any gas is the same whether the gas is consumed in atmospheric or in luminous burners, provided the combustion is complete in each case. There is thus no advantage to be derived from the use of the atmospheric burner in these appliances, and the luminous burner is adopted as being simpler, more cheerful looking, capable of giving off more radiant heat, and not liable to lighting back, with its accompaniment of incomplete combustion.

263. How does an incandescent gas burner differ from a luminous flame burner in the manner in which the light is produced from the gas, and how do you account for the difference in the amount of light which can be obtained from a cubic foot of gas by the two classes of burners?

Ans. An incandescent gas burner differs from a luminous flame burner in the way in which the heat produced by the combustion of the gas is transformed into light. As has been told in a previous answer, in a luminous flame the heat decomposes the hydrocarbons in the gas, forming particles of carbon, which it then raises to incandescence before they are consumed, and the light is given out by these incandescent carbon particles. The incandescent gas burner consumes the gas with a non-luminous flame in which there is no decomposition of the hydrocarbons, and the heat produced is employed to raise to incandescence a foreign body introduced into the flame.

The difference between the amounts of light produced per cubic foot of gas by the two styles of burners is thought to be due to two principal causes. In the first place, the substances of which the best incandescent bodies are made, namely, thoria and ceria, in the proportion of from 98% to 99% of thoria to from 2% to 1% of ceria, convert a larger proportion of the heat into light by converting the heat into the light rays which yield the greatest illuminating effect for the smallest expenditure of energy, that is, those forming the portion of the spectrum in and around the green, while the carbon particles in the luminous flame give off principally rays falling in the red and yellow portions of the spectrum, the lighting value of which is comparatively low.

In addition to this advantage it is thought that the temperature of the mantle is raised to a higher point than could be obtained solely from the heating effect of the flame from gas burning in air, by reason of catalytic action on the part of the ceria present. Cerium has the property of combining with oxygen in two different proportions, and Killing, a German chemist, has advanced the theory that under the action of heat the ceria in the mantle becomes alternately the higher and the lower oxide of cerium, thus absorbing and setting free oxygen. The oxygen set free is liberated at the surface of the mantle, the very point at which its effect in increasing the temperature of the flame will be most efficient in raising the mantle to a higher temperature. And since the light emitted by an incandescent body increases rapidly as the temperature of the body rises, the higher the temperature to which the mantle is heated the greater the amount of light it will give out. Dr. Bunte, another German chemist, took a different view of the way in which the effect is produced, and held that instead of actually combining with the oxygen the ceria simply condenses upon its surface the molecules of oxygen and thus makes them available for combination with the gas in a manner similar to that in which platinum acts when used in the form of platinum black in the self-igniting devices recently put on the market. The final effect of the action of the ceria is the same, no matter which view is assumed as being true, and is to increase the flame temperature of the gas, and, consequently, the temperature to which the mantle is raised, by making the combustion take place to a certain extent in an atmosphere of oxygen and so decreasing the amount of nitrogen that has to be heated for any given volume of gas consumed.

As a result of further research, and especially of some experiments upon the comparative temperatures of the naked flame of an incandescent burner and of a mantle heated by this flame, Dr. Bunte has abandoned the theory explained above, and now believes that the efficiency of incandescent gas lights is due to the selective radiation of the materials of which the mantle is made.

264. Upon what property of illuminating gas does the amount of light that it will give per cubic foot when used in an incandescent burner depend?

Ans. The authorities on the subject differ in their views as to the property of illuminating gas upon which depends the amount of light that it will give per cubic foot when used in an incandescent gas burner.

As a result of work done in connection with the Michigan Gas Association Scholarship in the University of Michigan, Messrs. White, Russell and Traver concluded that, other conditions being the same, the amount of light given per cubic foot by a gas when used in an incandescent gas burner was proportional to the calorific value and increased at the rate of one candle for each increase of four calories, or 15.87 B. t. u. in the calorific value per cubic foot. In their experiments they used an ordinary "C" Welsbach burner and a Welsbach mantle. The amount of gas as well as that of the air used with each gas was adjusted so that the maximum total amount of light was obtained, as they found that this condition corresponded with the maximum efficiency, that is, the giving of the maximum amount of light per cubic foot of gas consumed. The gases experimented with ranged from blue water gas to Pintsch oil gas.

After making a number of experiments with gases of different calorific values, the results of which were reported in 1903 to the International Commission on the Photometry of Incandescent Gas Burners, M. Sainte-Claire Deville also reached the conclusion that the lighting effect produced by gas used in incandescent burners was, apart from differences in the mantle, proportional to the calorific value of the gas.

On the other hand, Dr. H. Bunte reported to the International Gas Congress held in Paris in 1900, that he had found that gases differing widely in their calorific value gave practically the same results when used in incandescent burners. In the experiments on the result of which the statement was based, the same burner was used without any adjustment either of air or gas, and as this burner was designed for use with a gas of comparatively low calorific value, it did not give for the gases of higher calorific value the results that can be obtained when they are burned under proper conditions, and, therefore, the conclusion of Dr. Bunte is hardly justified.

Prof. V. B. Lewes holds that the flame temperature is of more importance than the calorific value of a gas in determining its efficiency in an incandescent burner, since the amount of light thrown off by any given incandescent material depends upon the temperature to which it is heated. On this basis the amount of air required for and the amount and character of the products formed by the combustion of the gas and the volume of the space in which the combustion of a unit volume of this gas is completed are as important as the calorific value. In the lectures in which he set forth these views Professor Lewes gives the results of experiments showing a duty of 19 to 20 candles per cubic foot from blue water gas when burned in a special form of Argand burner without any pre-admixture of air.

That the temperature of the incandescent body has an important influence upon the amount of light that it will give out is shown, among other things, by experiments made by Messrs. White, Russell and Traver, the results of which are given in the report mentioned above, and by the increased duty per cubic foot of gas which is obtained with the same gas and the same incandescent material by the use of high pressure and other forms of "intensified" incandescent burners. These burners differ from ordinary incandescent burners only in bringing about a better admixture of air and gas, and, by so doing, reducing the volume of the flame produced by the combustion of any given quantity of gas. It would, therefore, seem as if the flame temperature of a gas would influence its efficiency when used in incandescent burners, and should be taken into consideration as well as the calorific value. There is, however, very little difference between the flame temperatures of the different qualities of illuminating gas as ordinarily distributed, and the gases with the higher calorific values have also the higher flame temperatures. Moreover, the mantle never reaches either the theoretical or the actual temperature of the flame. Therefore, for practical purposes the efficiency of illuminating gas for use in incandescent burners may be taken as being proportional to its calorific value.

The reports and lectures referred to above can be found as follows:

The Theory of the Incandescent Mantle, by White, Russell and Traver, American Gas Light Journal, Volume LXXVI, page 413.

Lighting Power of Incandescent Mantles, by Sainte-Claire Deville, Journal of Gas Lighting, Volume LXXXIII, page 499.

The Future of Coal Gas and Allied Illuminants, Cantor Lectures, delivered before the Society of Arts, by V. B. Lewes, American Gas Light Journal, Volume LXXVIII, page 5.

265. Give a description, illustrated with sketches, of a Welsbach gas burner.

Ans. The Welsbach burner belongs to that class of lighting devices commonly known as Incandescent Gas Burners, in distinction from the Open Tip or Open Flame Burners, and is a burner in which the source of light is not one of the component parts of the gas itself, heated to incandescence by another part of the gas, but is a foreign body introduced into the flame (which is perfectly non-luminous) and heated till it glows.

The Welsbach burner consists primarily of a Bunsen burner and mantle; the gallery, air-shutter, chimney, etc., being added to give it practical value for general lighting purposes.

The mantle is made by saturating in a solution of rare earths, usually thorium and cerium, a web made from hard twisted, long staple cotton or Ramie fibre, both of which are natural products; or artificial cellulose may be employed.

In the upright type of mantles the most common form is now that having an asbestos loop at the top. Specially prepared asbestos cord is shirred into the top of the saturated webbing, twisted and tied to form a loop, or the asbestos cord may be tied within a metallic supporting ring, which is a continuation of the vertical side support attached to the burner cap. This side support is protected by a refractory magnesia clay tube. An additional fluid is applied to the head of the mantle for strengthening it either before or after this asbestos shirring operation. The cotton webbing is next burned away, leaving a soft, fragile, ashy structure, which is in turn hardened by being placed over a blow-pipe flame, other blow-pipe flames also acting upon the outside of the mantle. This not only hardens the ash, but gives the mantle its final form.

The mantle in this state would still be too fragile for transportation. It is, therefore, dipped in collodion, or a solution of nitrated cotton. After drying, the mantle, which up to this time has a rather ragged form at the bottom, is trimmed by special machinery, and either mounted on a supporting wire over a burner cap and gauze, or simply hung in a paper tube by means of a cord.

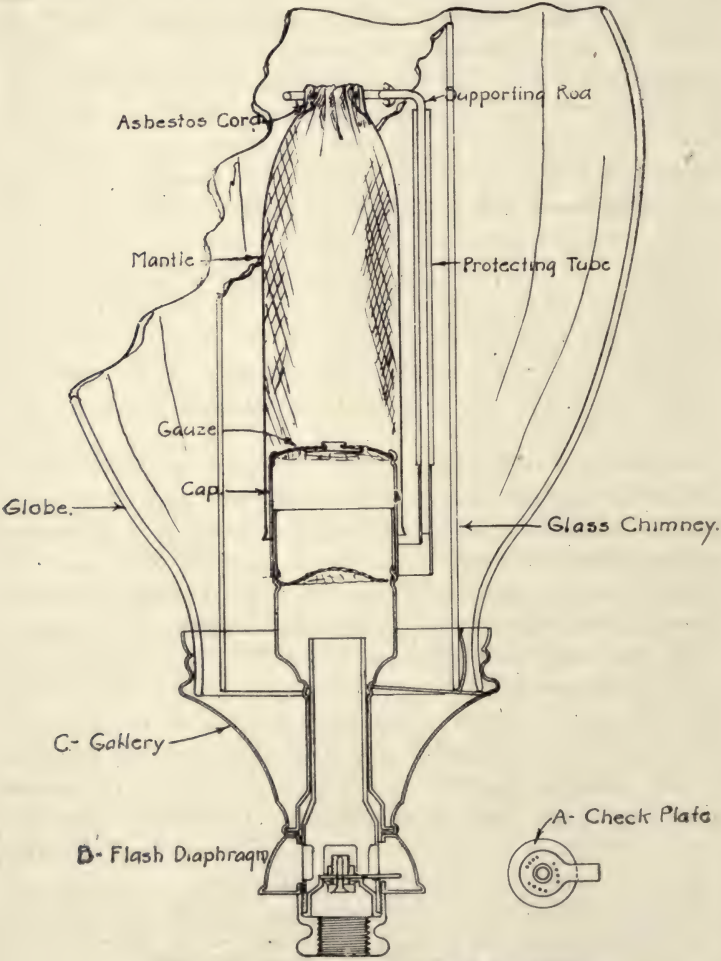
The inverted incandescent mantle has the same ashy structure as the upright form, but the saturated web is tied to an infusible supporting ring by means of asbestos cord at the top, the lower portion of the mantle being dome shaped.

The early type of incandescent gas burners employed simple Bunsen tubes, with non-adjustable gas checks. So much difficulty was encountered in securing the proper check, and there was so much variation, that some form of adjustable check became necessary. The modern type of incandescent gas burner is provided with an adjustable nozzle or check in its base, which may, at the will of the user, be adjusted to supply the proper amount of gas until the highest incandescence is obtained from the mantle. These adjustable gas checks are divided into two (2) general classes.

The first consists of a rotatable plate, pierced with a series of holes, which may be brought to register over circumferential slots, so that from one to all of the holes may pass gas upward into the Bunsen, depending upon the gravity of the gas and upon the pressure.

The second is the adjustable needle type of check, in which the needle is attached to a block that is moved vertically by a horizontal adjusting screw. Various ingenious motions have been designed to accomplish this needle adjustment.

A typical upright incandescent gas burner is shown on the cut.



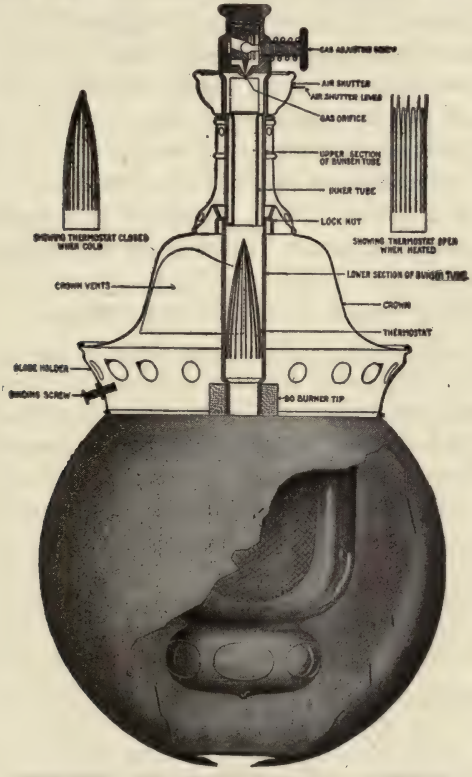
UPRIGHT INCANDESCENT GAS BURNER.

A shows top view of gas check.

B is known as the "flash diaphragm," which not only protects the air openings at the base of burner, but also engages the check plate, so that same may be adjusted by rotating B.

C is known as the "gallery," which supports the glassware. The gallery, C, carrying with it the mantle and glassware, is not fastened permanently to the Bunsen tube. It may be lifted off of the tube for cleaning purposes.

The inverted incandescent gas burner was evolved to eliminate the shadows which were necessarily produced by the brass structure beneath the upright burner, and while the Bunsen burner is still employed, it had to be considerably modified to burn in an inverted position. It was found that the gas and air mixture would not descend as readily as it would ascend in a heated tube, and furthermore it was not desirable to place any form of permanent impedance in the flow of this mixture. At the same time, some impedance is



INVERTED INCANDESCENT GAS BURNER.

required at the time of lighting the burner, to prevent the flame burning or flashing back to the gas check, and a thermostatic device was invented which would introduce an impedance to the flow of the mixture when the burner was first lighted, allowing the same to be lighted easily, without rupturing the mantle, and which when warm would be automatically removed, allowing the mixture an unobstructed path, insuring perfect and complete combustion. The mouth of the burner is protected with a refractory magnesia clay tip. The crown or shell of the burner is cut away, so as to allow the products of combustion to pass off to one side. The mantle, which is fastened to a magnesia clay ring, is fastened by means of a bayonet lock provided on the tip of the burner. The mantle is surrounded by a hard glass chimney, which is provided with a safety bottom, catching any particles which might drop from the burner. This construction allows, also, complete ventilation of the mantle, but does not allow the draughts of air to strike directly upon its surface.

The cut shows a typical inverted burner in section.

266. When globes are used in connection with flat flame gas burners, what effect does the size of the bottom opening of the globe have upon the light given out by the burner? How do the various materials of which such globes are usually made act in absorbing the light produced by the burner?

Ans. If the bottom opening of a globe used with a flat flame burner is made too small, the access of air to the flame is unduly restricted and the combustion of the gas tends to become imperfect. At the same time, the air entering through the bottom of the globe acquires a high velocity in passing through the small opening and causes the flame to flicker, in some cases even to smoke, just as would an open flame exposed to the wind. For these reasons a flat flame burner surrounded by a globe with a small bottom opening will not originally yield as much light as will the same flame burning in the open air in a space free from draughts. To avoid this detrimental effect no globe having a bottom opening less than 4 in. in diameter should be used over a flat flame burner.

In King's Treatise (Vol. III, page 35) the following table is given as showing the effect of shades made of the materials named, in absorbing light when placed over a gas burner:

	Loss of Light. Per cent.
Clear glass	10.57
Ground glass (entire surface ground)	29.48
Smooth opal	52.83
Ground opal	55.85

These figures are the results of experiments made in 1860 by Mr. W. King of Liverpool. It is to be presumed that the "shades" tested were the same as globes and that the tests were made with the light in the same horizontal plane as the photometer disc. It is not stated whether the burner used was an argand or a flat flame.

About 1880 Mr. F. W. Hartley also investigated this subject of the absorption of light by globes and gave the results of this investigation in a series of papers published in the Journal of Gas Lighting, etc. (Vol. XXXVII, pp. 54, 94, 134.) He determined the effect of globes upon the available light from both argand and flat flame burners, and for both horizontal lighting, that is, with the photometer disc on a level with the flame, and for overhead lighting, that is, with the flame above and to one side of the photometer disc, flat flame burners enclosed by globes being usually used mainly for the illumination of objects lying in horizontal planes below that of the lights themselves. From the results of his experiments he drew the following conclusions for horizontal lighting:

"That a clear glass globe increases the sensible light from a flat flame.

"That globes of ground glass obstruct less light than sheets of ground glass. That the percentage loss diminishes as the light grows stronger and is for an average light 18 to 20%.

"That opal globes obstruct an amount of light equal to from 33 to 65%."

The increase of sensible or available light found with a clear glass globe results from the fact that the amount of light absorbed by the glass in front of the flame is more than compensated for by the extra illuminating value of the flame due to the increased steadiness secured by the use of a properly designed globe and by the light reflected from the portion of the globe behind the flame. This reflection also explains the fact that globes obstruct less light than sheets of the same material.

For overhead lighting with the light 2 ft. 3 in. above the photometer disc and distant from it 2 ft. 0 in. along the horizontal line, that is, with the disc on a line passing through the light at an angle of 41° 38′ with the vertical, he found "that glass globes with flat flame burners increased the power of the light—clear globes about 6%; ground glass about 9%; albatrine (a species of opal) about 23% and German opal about 21%."

These figures, of course, only hold for the particular angle mentioned. At this angle the direct rays falling on the disc passed through the bottom opening of the globe and were, therefore, not subject to any absorption of light by the glass, and these direct rays were reinforced by light reflected from the upper portion of the globe. Had the angle taken been such as to cause the rays of light falling on the photometer disc to pass through the globe, the absorption of light would probably have been approximately the same as that shown in the horizontal lighting experiments.

The above refers to the ordinary globes with smooth surfaces and not to globes such as the Holophane, which are specially designed to increase the amount of light given out at certain angles.

267. What is a Holophane globe and how does it affect the useful light given by the source of light over which it is used?

Ans. The Holophane globe is a globe which diffuses the light from a light source enclosed by it in such a way as to make the whole surface of the globe appear luminous, and at the same time changes the distribution of light in vertical planes and throws a larger proportion of the total light in the direction which will prove the most useful for any particular case.

The diffusion of the light is effected by the combination of vertical corrugations on the interior of the globe, the effect of which is to spread the light horizontally, with horizontal prismatic mouldings on the exterior surface which spread the light vertically. The shapes of both the corrugations and the mouldings are carefully designed to secure the transmission of the largest possible percentage of the light through the glass, and the prisms forming the mouldings are also designed to refract as much as possible of the light in a definite direction. Thus one form of globe, used for lighting a desk or table by means of lights on a chandelier above it, is so made as to direct the larger proportion of the light downwards; another, used for the general illumination of rooms by means of lights on the chandeliers, distributes the light uniformly in the hemisphere below the horizontal plane passing through the light source, while still another form, used for street lighting, causes most of the light to be given off in the space between this horizontal plane and the cone generated by the revolution of a line drawn through the light source at an angle of 45° with the plane.

Each style requires special forms for the prisms on the exterior surface, and it is also necessary that the forms of these prisms on any one globe vary with their position relative to the source of light, since the rays of light cannot be refracted in parallel directions by prisms of the same shape, when one receives horizontal rays and the other rays at an angle of, say, 45° with the horizontal.

The use of Holophane globes is especially advisable with incandescent gas lights for two reasons. In the first place the intensity of the light is too great to permit of its being used unshaded for ordinary interior lighting. The diffusion effected by the Holophane globe overcomes this objection with the least possible loss of light, since, owing to their design, these globes absorb very little more light than is absorbed by plain glass, while an opal or tinted globe sufficiently dense to cut off the direct view of the light source will absorb a large proportion of the total light emitted by the source. In the second place, the light emitted by a naked incandescent light is, owing to the shape of the mantle, given out principally in a horizontal direction, and so is not available, when, as is usually the case, the light is above the surface to be illuminated. By changing the direction of the rays the Holophane globe actually increases the amount of light made useful in cases of this kind, the absorption of the glass being more than counterbalanced by the extra rays drawn aside from the illumination of space where only a slight illumination is needed and made to take a more useful direction. The total spherical illumination, that is, the illumination of the whole space surrounding the light, is of course diminished by an amount equal to the light absorbed by the globe, the increase in the amount of light at the points where it is to be used being obtained at the expense of the amount at the points where it is not needed.

Appliances.

268. What are the different forms of atmospheric burners usually employed for the top burners of gas cooking stoves, and which form do you consider the best for this purpose? Give the reasons for your choice.

Ans. The different forms of atmospheric burners commonly employed for the top burners of gas cooking stoves may be classed as ring burners with drilled holes, radial or star burners with drilled holes, ring burners with slits sawed in them, and star burners with sawed slits. Annular slit ring burners and serrated disc, or cap burners, are also sometimes employed, but the drilled or sawed burners are the only ones used on the better class of stoves.

One series of careful experiments seems to show that given equally good design in other directions, as, for instance, in the form and size of the air mixers, the drilled ring burners possess the greatest efficiency, that is, enable the largest proportion of the total heat given by the gas consumed to be utilized in useful work. Next to the drilled ring burner comes the drilled radial burner, followed by the sawed ring and the sawed radial burners in the order named.

In the answer of one of the members of the class, who has made a number of tests of gas stove burners, ring and star burners are compared as follows :

"There are two general shapes of burners, the ring and the star. The efficiency of the one as compared to the other will run about the same, but the star burner offers the advantage over the ring in that it is possible to drill more ports on its surface and so a higher rate may be burned on it with good combustion.

"By this is meant that, taking a star burner and a ring burner, both of which are set 1¼ in. from the bottom of the vessel and burning 10 cubic feet per hour, it will be found that the efficiency will be about the same, but if the consumption is increased to 13 cubic feet per hour, it will be noted that the efficiency of the star burner will only drop about 2%, while the ring burner would not do at all because of the poor combustion. To drop the burner to get proper combustion means to drop the efficiency.

"In this point lies the advantage of star over ring burners, with the one exception of a ring burner in which there is a double row of ports and a ventilated space between the two rows.

"I prefer a cored cast star burner, 4¼ in. in diameter, eight arms and forty-eight No. 40 gauge ports spaced $\frac{5}{16}$ in. apart from centre to centre and with the ports around the centre air well drilled at an angle of about 60°, the flame pointing in toward the centre of the burner.

"This burner will give as high an efficiency as any other burner, and will permit of a maximum rate per hour with good combustion and proper efficiency."

It is, however, undoubtedly true that the average ring burner gives a better efficiency than the average star burner because in the former there is a better supply of air to all parts of the flame, owing to the fact that the air is free to rise on the inside as well as the outside of the ring, while in the star burner, unless very well designed, the access of air to the gas issuing from the central portions of the burner is very much obstructed. The greater efficiency of the burners with drilled holes, as compared with those having the orifices in the form of slits, is probably due in part to the greater opportunity for free access of air to all parts of the several jets of flame that is given by the drilled form, and partly to the smaller ratio of perimeter to area of circular as compared with rectangular orifices, which affords a smaller contact between flame and burner and consequently a smaller abstraction of heat from the flame by the burner. It is an observed fact that in other forms of non-luminous burners the circular aperture gives much the best results, and this rule seems to apply as well to the atmospheric burners used for gas stoves.

269. In setting a gas range which has an oven burner and four top burners, what size of pipe should be used, and to what size meter should it be connected? Give the reasons for your answer.

Ans. A gas range having four top burners and an oven burner should be connected to the meter by a $\frac{3}{4}$ in. pipe, if the range is not more than 50 ft. to 60 ft. from the meter, and by a 1 in. pipe if the distance is greater than this. The meter should not be smaller than 5-light.

A gas range of this description will consume, when all the burners are in use and burning full, at least 60 cubic feet of gas per hour. On a length of 50 ft. the passage of gas at this rate through $\frac{1}{2}$ in. pipe would result in a loss of pressure of from $\frac{4}{10}$ in. to $\frac{7}{10}$ in., according to the specific gravity of the gas, the limits taken for the specific gravity being 0.400 and 0.700. Even the smallest loss is too large, and therefore $\frac{3}{4}$ in. pipe must be used. On a run of 60 ft., $\frac{3}{4}$ in. pipe will, at the above rate of consumption, cause a loss of pressure of $\frac{2}{10}$ in., with gas having a specific gravity of 0.700, so for runs longer than this 1 in. pipe should be used, since, unless the pressure in the street mains is high, it is not advisable to lose even $\frac{2}{10}$ in. pressure in the piping.

According to a table given in a paper entitled "The Measurement of Gas," read in 1897 by Mr. C. W. Hinman, before the New England Association of Gas Engineers, and published in the American Gas Light Journal, Vol. LXVI, page 401, a 3-light meter, passing 60 cubic feet of mixed coal and water gas per hour, causes a loss of pressure of 0.37 in. Mr. Hinman does not consider this loss too large, and concludes that a 3-light meter is large enough to supply a gas range if this is its sole duty. But a loss of this amount of pressure added to the loss suffered in the piping would, in most localities, make the pressure at the gas orifices of the range burners so low that it would be impossible to obtain a good atmospheric flame, and in practice it has been found best to use a 5-light meter with a range of this description, even when the meter supplies nothing but the range. It is even more necessary that nothing smaller than this size should be used when the meter has to supply the gas for lighting the house as well as that needed for the range. In fact, if the range is a large one, consuming, say, 80 to 100 cubic feet per hour, when all the burners are in use, a 10-light meter will be required to satisfactorily supply gas for both the range and the house lighting.

270. How would you test various samples of gas cooking stoves to determine which was most economical of gas and at the same time did the best cooking?

Ans. The comparative efficiency of the top burners of various samples of gas stoves may be tested by determining the length of time and amount of gas required to heat a definite quantity of water from a temperature of, say, 60° F. to the boiling point. The same kettle should be used throughout the tests, and the weight of water employed, its temperature at the start, the exact time at which it begins to boil, and the amount of gas consumed, must be accurately determined in each case.

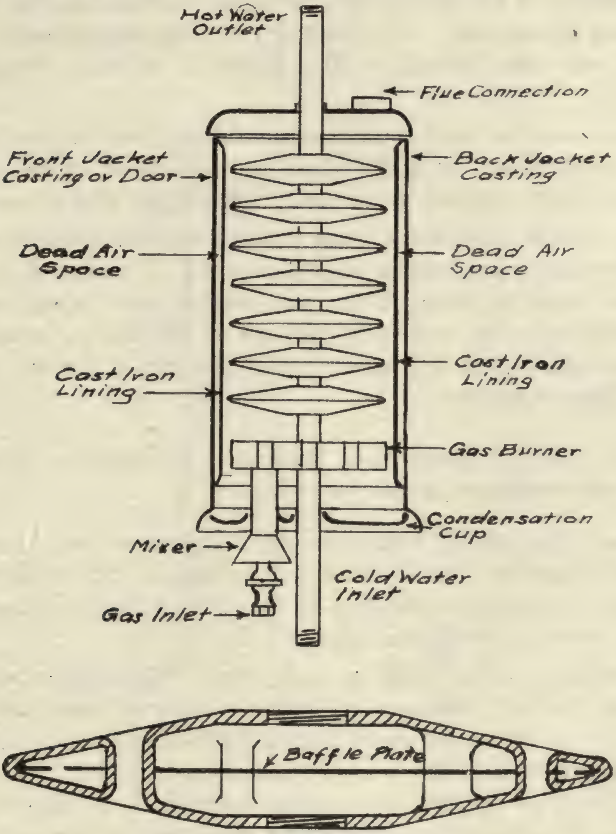
The efficiency of the ovens may be tested by determining the time and amount of gas required to bring each oven up to a baking heat and then to bake a definite weight of either bread or biscuit. The dough must be all ready to put into the oven as soon as the required heat is attained, so that no gas is wasted while waiting for the dough to be gotten ready, since any delay of this kind would spoil the tests. Each oven should also be tested for evenness of distribution of the heat throughout its whole interior. This can be done by placing pieces of white writing paper in different parts of the oven, and noticing the extent to which the different pieces are browned when the oven is hot enough to bake. The more nearly they all approach to the same color the more uniform is the distribution of heat throughout the oven, and the better will it bake. As a rule, the ovens that show a good efficiency by the baking test will also show a uniform distribution of the heat.

271. Give a description, illustrated with sketches, of one or more forms of circulating gas water heaters for use in connection with ordinary kitchen boilers.

Ans. One form of gas water heater for use in connection with a kitchen boiler is made in the shape of a cylinder about 10 inches outside diameter and about 30 inches long over all. This heater is suspended by the side of the boiler by means of the water connections. On some of these heaters the cold water pipe is extended down to the floor to give extra support and ease the strain on the water connections.

The cylindrical casing or jacket of this heater is made of cast iron, in two pieces, one half the front, or door, being hinged so that it will open for lighting, while the other, or back casting, is bolted fast to the top and bottom castings. This construction allows easy access for cleaning and inspecting, and prevents the danger of a serious explosion due to improper lighting of the gas. Both of these jacket castings are lined with a cast iron shell, which fits closely to the jackets, and leaves about $\frac{1}{4}$ in. dead air space between the casing and this inner shell.

The internal or water carrying part of this heater is made of a series of cored, flat, circular brass or iron castings, screwed together by close nipples. These castings should preferably be of brass, as there is a tendency of the iron to rust and discolor the water. The water, entering through the centre of the burner at the bottom by a $\frac{3}{4}$ in. pipe, is forced to circulate first to the outer edge of the section casting by a sheet baffle cast in the section, and then in over the top of the baffle to the upper nipple. This is repeated in every section of the heater, the water finally flowing out through a $\frac{3}{4}$ in. pipe at the top of the heater and so to the boiler.



Section of Internal

CIRCULATING GAS WATER HEATER.

The burner is an atmospheric star type burner, having the ports drilled in lugs cast on the top of the arms, and a central round hole through which passes the cold water inlet pipe. The mixing tube and air mixer are cast in one piece, which is fitted into the burner with a ground joint, and held in place by a set screw. The burner is capable of handling between 35 and 60 cubic feet of gas per hour.

The hot products pass from this burner over the bottom of the sections and up through the cast holes in each section to the next above. The water, being in a thin sheet between the bottom of the section and the baffle, becomes heated, thus causing circulation. The products of combustion finally find their way out through a flue collar in the back of the top casting.

Care must be taken to keep the flame from impinging on the lower section, since if it does the combustion of the gas is checked and rendered incomplete, and the gas will be wasted.

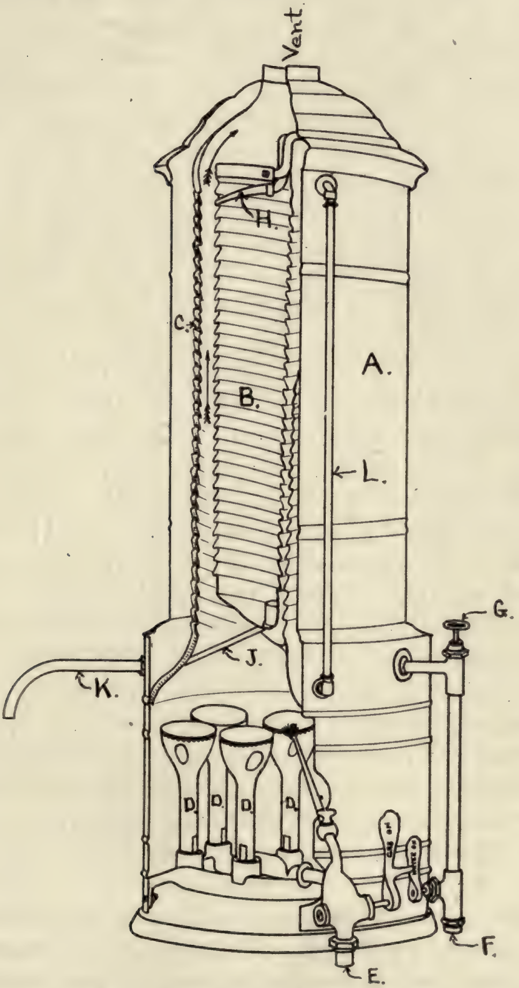
At present there are a large number of water heaters made with copper coils, instead of cast sections. These coils are set in the jacket in place of the cast section, but the cold water connection in this case is in the side of the casing, instead of in the bottom, the hot water outlet leaving at the top, as in the heater described.

272. Give a description, illustrated by sketches, of some form of instantaneous gas water-heater.

Ans. The name ''Instantaneous'' is given to two classes of water-heaters in which the water is heated at the time it is needed. Heaters of this class do not furnish any heated water to be stored up for future use.

The first is what may be called the ''Bath Instantaneous Heater,'' which does not deliver water at a sufficient head to enable it to be carried more than a few feet from the outlet of the heater itself. They work by causing the water that is to be heated to flow in thin streams over one surface of thin copper sheets, of comparatively large area, the other surface of these sheets being exposed to the heated products of the combustion of a comparatively large quantity of gas.

The heater illustrated on the accompanying cut consists of a copper cylinder, A, about 1 foot in diameter by 3 feet high, in which two spirally corrugated copper tubes, B and C, are set, the bottoms of these tubes being a sufficient distance above the bottom of the outer cylinder to leave ample space for the gas burners, D, D, D, and also for a combustion chamber, above these burners, in which the combustion of the gas can be completed before the products strike the water-cooled surfaces of the tubes. The inner tube, B, is provided with a closed bottom, but is open on top. The outer tube, C, is



BATH INSTANTANEOUS WATER HEATER.

fastened all around its bottom with a water-tight joint to the inside of the outer cylinder, A, and its top fits snugly against the vent opening at the top of the cylinder. The axis of each of the tubes and that of the cylinder all coincide, and the annular space between the tubes is about 1 in. wide.

Gas is supplied by means of a pipe, E, which should be $\frac{3}{4}$ in. in diameter. A pilot light is used to light the gas at the main burners, as shown. The lever of the main gas cock has on it an arm so arranged that as the gas cock is opened this arm opens the main water cock on the pipe, F. It is thus impossible to turn on the gas without turning on the water, and there is no danger of the heater being damaged by being exposed to excessive heat owing to the gas being turned on while the water is shut off. After passing the main cock the water goes through a regulating valve, G, by which the quantity flowing can be regulated to suit the requirements as to the temperature at which it is to be delivered. It is then carried, by a pipe inside the inner tube, up to the top of this tube. From the end of this main supply pipe branches are led to deliver the water directly on the inner surface of the inner tube and the outer surface of the outer one. One of these branches is shown at H. The water flowing over the inner tube follows the corrugations to the bottom, whence it flows through the pipe, J, into the bottom of the space between the outer tube and the cylinder, in which is also collected the water that has followed the corrugations of the outer tube. From this space it is delivered through one or more pipes, K, to the point, or points, where it is wanted.

As will be seen from the cut, the only outlet for the products of the combustion of the gas is up through the annular space between the corrugated tubes. This space being narrow the products are brought into close contact with the metal and rapidly impart to it their heat to be taken up by the water flowing over it. As the products and the water travel in opposite directions, the water as it is heated flows over surfaces that are more and more highly heated, and so is able to take up heat until it leaves the heater. The products of combustion, becoming cooler and cooler as they ascend, finally leave by the vent opening, which should always be connected to the outside air.

A gauge glass, L, is provided to show the height at which the water stands in the space between the outer tube and the cylinder, and thus call attention to the necessity for checking the flow by the regulating valve should the water be running in faster than it can be carried off by the delivery pipes.

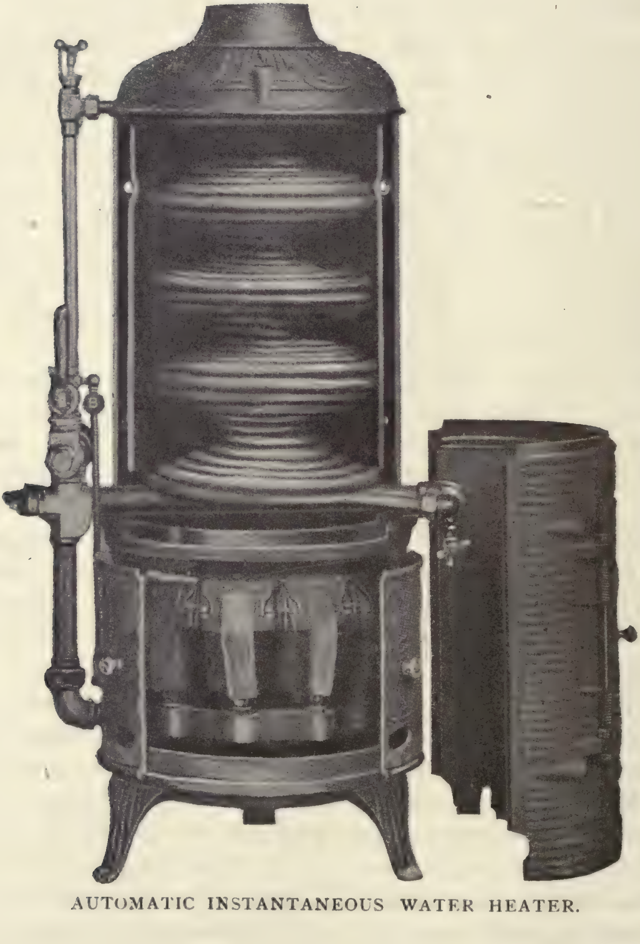
Heaters of the style shown on the cut contain 10 to 11 square feet of heating surface, will raise the temperature of the water by 50° F. when it is flowing at the rate of from 1½ to 2 gallons per minute, and will consume about 1 cubic foot of gas for each 1 to 1½ gallons of water heated.

As will be seen by the cut, the water and the products of combustion do not come into contact with one another in such heaters, and the water heated by them can be used for cooking as well as for washing. Another style of heater is made in which the water and products of combustion do come into contact with each other, and such heaters can be used only for water that is not to be taken internally.

The second, usually called "Automatic Instantaneous Heater," is constructed of large copper coils heated by a set of individual Bunsen burners of large capacity. These heaters may be situated in the cellar and connected to the hot water supply of the house, thus heating water for use at any spigot in the house. The capacity of this type of heater is from two to eight gallons of water a minute, which is raised through a range of about 60° F. The heaters are controlled by a water valve and thermostat turning on the gas to the burners, which are lit by a permanent pilot burner.

When the water is turned on at any spigot the pressure of the water in the hot water pipe is reduced and allows the excess pressure of water in the cold water pipe to open the gas valve, which is usually kept closed by a spring. The opening of this water valve turns on the gas to the main burners.

The amount of gas fed to the burners is regulated by the thermostat, which keeps the water discharged at a given temperature; turning on more gas when the water falls below this temperature and cutting down the gas when the temperature gets too high. The efficiency of a heater of this type is very high and the results obtained have been very satisfactory.



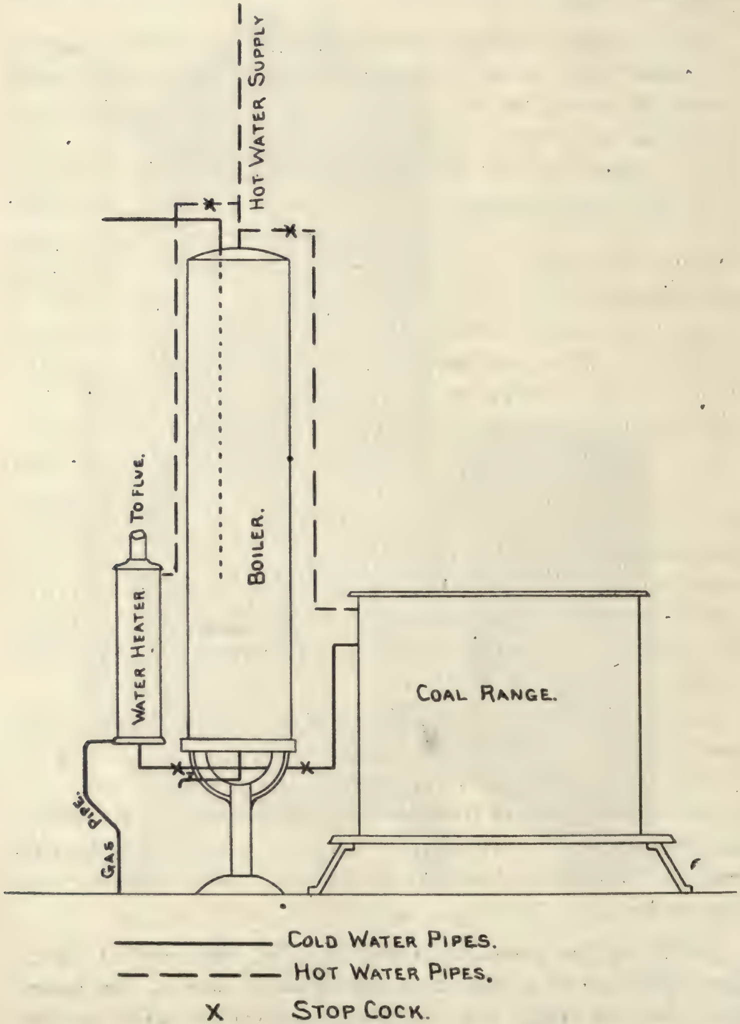
AUTOMATIC INSTANTANEOUS WATER HEATER.

273. Give a description, illustrated with outline sketches, of the connection of a circulating water heater to a vertical hot water boiler. Assume that the boiler is already connected to a coal range.

Ans. In connecting a circulating water heater to a vertical hot water boiler of the ordinary kitchen style, the bottom of the heater should be put about on a level with the bottom of the boiler in order to secure the best circulation. The cold water connection for the heater should be taken from the cold water pipe running from the bottom of the boiler to the water back of the coal range and the hot water pipe from the heater brought up and connected into the hot water supply pipe running out of the top of the boiler. This method of connecting, which should be followed even in the case of the water back of the coal range, compels all the cold water in the boiler to pass through the heater before any heated water can pass through a second time and enables the hot water to be drawn within a few minutes after lighting the gas in the heater instead of having to wait until all the water in the upper part of the boiler has been heated, as is necessary when the hot water pipe opens into the boiler at a point in the side about one-third of the height above the bottom, and will permit the securing of great economy in the use of gas, especially when small amounts of very hot water are required several times a day.

Stop cocks may be arranged, as shown, so that either the gas heater or the water back of the coal range can be shut off without interfering with the use of the other, but they are liable to cause serious trouble if they are closed accidentally and the heater is started while they are closed, and for this reason it is better to have the connections made without any stop cocks.

In the cut the gas water heater has, for the sake of clearness, been shown as placed on the opposite side of the boiler from the coal range, but the connections can be made equally well with the heater in any other position, and to save space it is often desirable to place it in front of the boiler on the side towards the coal range. When this is done it may not be possible to make the connections exactly as shown on the cut, but the same general arrangement should be adhered to. All the pipe and fittings used for water connections should be made of galvanized iron and should be large enough to permit a free flow of the water so that the circulation through the heater will not be checked.



274. A gas water heater has an efficiency of 75%. It burns 45 cu. ft. per hour of a gas having a calorific value of 595 B. t. u. Assuming that a gallon of water weighs 8.33 lb., how many gallons per minute can it heat from a temperature of 50° F. to one of 130° F.? Give your calculations.

Ans. The total number of B. t. u. produced in one hour by the combustion of the gas under the assumed conditions will be $595 \times 45 = 26{,}775$, but since the efficiency of the water heater is 75%, the number of B. t. u. available for heating the water will only be $26{,}775 \times 0.75 = 20{,}081$ per hour, which divided by 60 gives 334.68 per minute.

A B. t. u. being the amount of heat required to raise the temperature of one pound of water 1° F., there will be required to raise the temperature of one gallon, weighing 8.33 lb., from 50° F. to 130° F. $8.33 \times (130-50) = 8.33 \times 80 = 666.40$ B. t. u.

Then

$$\frac{334.68 \text{ (whole number of heat units available)}}{666.40 \text{ (number of heat units required per gallon of water)}} =$$

0.5 equals the number of gallons of water the temperature of which can be raised the required amount in a minute.

275. An instantaneous water heater burning gas at the rate of 81 cubic feet per hour will heat water from a temperature of 54° F. to 117° F. at the rate of 72 gallons per hour. The gas has a calorific value of 650 B. t. u. per cubic foot. What is the efficiency of the heater?

Ans. Under the conditions stated in the question the amount of heat developed in the heater per hour by the gas used is 81 (number of cubic feet of gas consumed per hour) $\times$ 650 (calorific value of a cubic foot) $= 52{,}650$ B. t. u. The useful work done is measured by the amount of heat put into the water passing through the heater. The temperature of the water is raised $117 - 54 = 63°$ F. and the weight heated to this extent is 72 (number of gallons heated per hour) $\times$ 8.33 (weight of a gallon of water in pounds) $= 599.76$ lb. Therefore, the gas consumed does an amount of useful work equal to $599.76 \times 63 = 37,785$ B. t. u. and the efficiency of the heater is $\frac{37785}{52650} = 71.7\%$.

276. What are the arguments in favor of the use of gas engines in place of steam engines, especially for small sizes, that is, up to 15 or 20 H. P.?

Ans. Ordinarily the cost of a gas engine of the sizes specified is about equal to the combined cost of a steam engine and boiler of the same capacity, and except in cases where a boiler plant is already in use for other purposes, and has sufficient margin for the extension required, the investment in a gas engine is no greater than for an equivalent steam plant.

The cost of fuel for a gas engine and for a steam engine is, under ordinary working, approximately the same for the sizes specified. For the steam engine it would be, say, 10 lb. of coal at $4.00 per net ton, equal to 2c. per H. P. hour. For the gas engine it would be 20 cu. ft. of gas at $1.00 per 1,000 cu. ft., equal to 2c. per H. P. hour.

From this point on the advantages and economy are all in favor of the gas engine.

1. No boiler is required, with its mechanical accessories, including coal and ash storage, so that less space is required, thus saving in rental, taxes, insurance and depreciation.

2. There are no coal and ashes to handle, and there is no smoke.

3. There is less fire risk and less danger of explosion.

4. There is no waiting to get up steam, for the gas engine can be started or stopped immediately, and the expense does not begin until it is started, and ends when it is stopped.

5. The wages of fireman and engineer are saved.

6. A gas engine of the sizes specified can generally be located on any floor of a building, thus saving in shafting and belts, and in the loss of power incurred by their use.

277. When a gas engine is connected to a comparatively small street main, its operation will, unless special precautions are taken, cause a fluctuation in pressure which may affect

the use of lighting and cooking appliances in the neighborhood. What means would you employ to prevent such a fluctuation in pressure from being produced in the street main when the engine is running?

Ans. This question was brought up and discussed at the 1903 meeting of the American Gas Light Association, and several methods of overcoming the fluctuation of pressure were described.

The simplest method, which, however, applies only where the load is fairly constant, is to put a stop cock on the inlet to the gas bag and, by partly shutting the cock, compel the gas to pass into the bag at a practically uniform rate just sufficient to supply the quantity of gas required by the engine. The bag acts as a reservoir which is emptied when the engine draws gas, and is filled again during the interval between explosions, and as the pull on the portion of the pipe in front of the stop cock is kept more constant the fluctuation in pressure is reduced. This method will give slightly better results when two bags are used in tandem instead of one. When it is employed care must be taken not to shut off the stop cock to such an extent as to prevent the engine from getting all the gas it requires and thus to prevent it from developing the power needed.

A more elaborate method based upon the same principle is to use a diaphragm governor followed by a reservoir or tank from which the engine draws its gas. An ordinary kitchen boiler will make a good reservoir. Sometimes a length of pipe of a diameter larger than that of the rest of the run between the regulator and the engine is used as the reservoir.

This method gives good results with engines running at relatively high rates of speed or with multiple cylinder engines which draw gas at a comparatively steady rate, but with large single cylinder engines running at slow speeds the simple reservoir must be made very large. In such cases a reservoir is used which is partly filled with some non-volatile liquid, one portion of the surface of which is in communication with the outside air, while gas stands in the part of the reservoir over the rest of the surface. This part of the reservoir is in direct communication with both the engine and the service pipe. When the engine pulls gas the pressure in the reservoir is reduced and the air acting on the liquid forces it up into the gas space, and thus drives gas out from this space to the engine. In the intervals between the suction strokes of the engine the supply of gas in the reservoir is replenished from the service and the liquid brought back to its normal level.

A small gas holder will, under the same conditions, absolutely prevent the passing back to the street main of any fluctuation in pressure, no matter how much the load varies, but such a holder is comparatively expensive.

All of these methods employ the same principle, that of having a store of gas, fed at a constant rate, from which the engine can draw its supply without reducing the pressure as much as if it drew directly from the service.

278. What are the conditions leading to efficiency of working in a gas engine?

Ans. The essential conditions for efficiency in a gas engine are,

1. The largest volume of cylinder with the smallest circumferential surface; in other words, the largest diameter of cylinder.

2. Maximum speed of piston.

3. Greatest possible expansion.

4. Highest possible pressure at the beginning of the explosion.

These conditions were first laid down by Beau de Rochas in 1862. They all tend to insure the least possible loss of heat from the cooling effect of the walls of the cylinder and through the exhaust, and, consequently, tend to secure the greatest possible utilization of the heat produced by the combustion of the gas and therefore the greatest possible efficiency of the gas engine.

279. How does the calorific value of gas affect the consumption per horse power in a gas engine, and what do you

consider a fair average rate of consumption per brake horse power for a 10-horse engine using a gas having a calorific value of 600 B. t. u. per cubic foot.

Ans. A gas engine is a heat engine, that is, an engine in which energy in the form of heat is converted into mechanical energy, and, since a definite amount of heat is required to produce any given amount of mechanical energy, it follows that the greater the calorific value of the gas used in a gas engine the smaller the amount required per hour per horse power developed. If the gas engine were capable of using, with the same efficiency, gases of any calorific value, the respective amounts of the different gases required per hour per horse power would vary inversely as their calorific values. It is found, however, that for various reasons gas engines work a little more efficiently when using gas of comparatively low calorific value, 150 to 300 B. t. u. per cubic foot, than they do when using gas of higher calorific value, 500 to 1,000 B. t. u. per cubic foot, so that they require somewhat less of the low value, in comparison with the higher value, gas than is called for by the relation between the calorific values.

In any case, the consumption of gas per horse power will vary with the condition in which the engine is kept and upon the proportion between the load it is carrying and that which it is capable of carrying, since when working at or near its full load the engine has a greater mechanical efficiency than when running under a small load. Under favorable conditions a 10-horse power gas engine can be run on a consumption of 20 cu. ft. per brake horse power per hour when using gas of a calorific value of 600 B. t. u., but the average consumption under actual working conditions will be about 25 cubic feet per brake horse power per hour.

280. Describe the cycle or series of operations and the method of governing employed in each of the following gas engines: Otto, Westinghouse, and Körting.

Ans. The so-called "Otto cycle" in gas engines is a four-phase cycle carried out in a single-acting cylinder open at the end toward the crank, and provided with a tightly-fitting piston which is free to move back and forth.

Starting with the piston at the beginning of an out-stroke the cycle is as follows: As the piston moves out on the forward stroke, the charge of gas and air is drawn in and fills the cylinder. The in or back stroke compresses the charge into the clearance space. At the dead point at the end of this second stroke, the charge is ignited and the resulting explosion drives the piston out on its second forward stroke. The succeeding in-stroke expels the products of combustion from the cylinder and the cycle is completed, the piston being in its first position and ready to repeat the same series of operations. It will be seen that the cycle requires four strokes of the piston for its completion, and that of these four, the third is the only motor-stroke, the power required to carry on the others being derived from the energy stored in the fly-wheel during the third stroke. It will be seen also that there is only one explosion for each two revolutions of the fly-wheel.

This cycle was first described and advocated in 1862 by M. Beau de Rochas, and is properly called the Beau de Rochas Cycle, but it was not put into practical use until 1876, when it was adopted in the Otto Silent Engine, the first gas engine that was commercially successful and one which held the field almost to the exclusion of all others until the patent expired.

The Otto engine is governed on what is known as the "hit or miss" principle, that is, either a full charge or no charge at all is taken into the cylinder and exploded, the governor working on the gas valve in such a way that no gas is admitted to the cylinder as long as the engine is running at its normal speed, the valve opening only when the number of revolutions falls below that for which the governor is set. Thus, when running on a light load the engine may miss either every other explosion or two out of every three, or so on, according to the load. This method of governing by admitting charges of full size only, makes the degree of compression of every charge the same, and thus causes all the gas to be employed under the most economical conditions for any particular engine, but it permits, in fact depends upon, comparatively wide variations in speed, and therefore is not satisfactory when close speed regulation is important.

The Westinghouse gas engine also employs the Beau de Rochas four-stroke cycle, but has always two cylinders, and in the larger examples three, the pistons working in which are connected to the same crank shaft, thus securing in the smaller sizes one working stroke to each revolution, and in the larger three working strokes to each two revolutions.

The speed is governed, not by the "hit or miss" method of doing away with the explosions entirely when the speed runs above the normal, but by regulating the amount of the explosive mixture admitted to the cylinder in each complete cycle in a manner similar to that employed for governing steam engines. In this way an explosion is secured in each cylinder for each four strokes, but the force of the explosions is varied in accordance with the amount of work to be done. The ports of the valves regulating the admission of gas and air to the cylinder are so arranged that their areas can be adjusted to give a mixture containing the desired proportions of air and gas entirely apart from the action of the governor, which simply controls the length of stroke of these valves, so that varying quantities of a mixture containing always the same proportions of air and gas (so long as the adjustment spoken of above is unchanged) are admitted into the cylinder. This method of governing keeps the speed more uniform than the "hit or miss" method, but since the volume of the charge is varied for each cycle the amount of compression is also varied and the engine is not always working at the most economical degree of compression. For this reason an engine so governed uses more gas per horse power per hour, other things being equal, than does one governed in the other way. However, when the work to be done calls for great uniformity of speed, the loss in economy may easily be more than counterbalanced by the closer speed regulation, especially when gas is cheap.

As originally made in small sizes, the Körting engine also employed the Beau de Rochas Cycle in a single acting cylinder, the governing being done by varying the strength of the charges. As now made in large sizes, 500 H. P. and over, with especial reference to the use of blast-furnace gas, the Körting is a two-cycle double-acting engine, with two explosions for every revolution. The two-cycle working in the main engine cylinder is secured by the use of two auxiliary pump cylinders, one being used for air and the other for gas. These two pump cylinders are in line and their pistons are fastened on a common rod driven by a crank set at an angle of 110° in advance of the main crank of the engine. The connections between the pumps and the main cylinder are such that gas and air from the rear end of the pumps can pass only to the rear end of the cylinder and vice versa.

Considering the main piston as starting from the rear end of the cylinder, it travels forward until it uncovers the exhaust ports, which are located in the middle of the cylinder and are unprovided with valves, being opened and closed by the main piston itself. As soon as these ports are uncovered the pressure in the rear of the cylinder falls to atmospheric and the admission valve is opened slightly before the piston reaches the end of the forward stroke. During the latter part of the forward travel of the main piston the pump pistons have been travelling backwards and air has been compressed into the air pressure pipe. The gas pump valves are so arranged that the gas is not compressed at as early a point in the stroke as is the air, and as the air pressure pipe and the gas pressure pipe both deliver into a common valve chamber, the opening from which into the cylinder is controlled by a single valve, the air which is being delivered at a higher pressure at the moment the admission valve opens forces back the gas and at first only air enters the cylinder. The exhaust ports being still uncovered this air first forces the products of combustion out of the cylinder, and then, as the ports are closed, is supposed to form a layer next to the piston, leaving at the back of the cylinder a mixture richer in gas than would be the case if gas were admitted from the first. As the pump piston travels back the gas becomes compressed in the rear end of the gas pump, and, the excess of pressure in the air pipe and the rear end of the air pump having been reduced by the escape of part of the air into the main cylinder at atmospheric pressure, both air and gas pass into the cylinder until the admission valve closes as the pump pistons reach the rear ends of the cylinders. The proper proportion between gas and air is secured by having the areas of the air and gas cylinders bear the desired relation to each other.

By the time the admission valve closes the engine piston has traveled through almost half of its backward stroke. During the rest of this stroke the mixture of air and gas is compressed, and when the stroke is completed this mixture is ignited, and by its combustion forces the piston out on the forward stroke. An exactly similar set of operations occurs in the forward ends of the main cylinder and the pump cylinders, and is repeated at each end of the cylinders for each revolution.

The governing of the Körting engine is done by varying the strength of the charge, but in a different manner from that employed in the Westinghouse. In the latter the proportion between the amounts of air and gas is always the same, no matter how small the charge. In the former the quantity of air admitted is not changed, the governor controlling only the quantity of gas used. This is done by changing the time at which compression begins in the gas pump, and thus the time at which gas begins to enter the engine cylinder, the admission of gas being advanced or retarded as more or less power is required. During the time that the gas is entering the cylinder it is mixed with the chosen proportion of air, and it is claimed that this mixture forms a layer at the end of the cylinder and is not diffused to any great extent through the air that is first admitted, and that thus certainty of ignition is secured even with small quantities of gas. The volume of air being the same for every charge, the total volume of the charge and therefore the degree of compression does not vary as much as in the case of engines governed as is the Westinghouse.

281. Describe the complete cycle, or series of operations, employed by each of the following gas engines: Clerk, Griffin, and Atkinson Cycle.

Ans. The Clerk engine employed the Beau de Rochas Cycle, but secured an explosion in the motor cylinder to each revolution by the use of an auxiliary cylinder called the displacer cylinder. The piston working in this cylinder was connected to the crank shaft at an angle of 90° in advance of the motor piston. It therefore began its out-stroke, drawing the charge of air and gas into the displacer cylinder, when the motor piston was at the middle of the in-stroke, and continued this out-stroke until the motor piston had passed its inner dead point and returned to the middle of its out-stroke. The displacer piston then began its in-stroke, slightly compressing the charge, and soon after the continued outward travel of the motor piston uncovered the exhaust ports near the front end of the motor cylinder and thus reduced the pressure of this cylinder to that of the atmosphere. The pressure in the displacer cylinder was now higher than that in the motor cylinder and lifted an automatic valve in the communicating passage between the two cylinders, and the charge entered the motor cylinder, where it was expanded by the heat of the walls, and swept out ahead of it through the open exhaust ports the products of combustion from the previous explosion. The motor piston had now reached the end of its out-stroke, and returning on the in-stroke covered the exhaust ports, and put a pressure on the charge in the motor cylinder. The automatic valve immediately closed, cutting off the communication with the displacer cylinder, the charge was compressed into the clearance space of the motor cylinder, ignited at the dead point of the motor piston and the explosion took place, forcing the motor piston out again, the displacer piston being half a stroke ahead. By the series of operations above described this engine not only secured an explosion for each revolution, but also got rid of almost all of the products of combustion. It was economical compared with other engines made at the same time, but is no longer manufactured.

The Griffin engine in its older form, to which the question refers, was what is called a six-cycle engine, that is, one using a cycle giving only one explosion in six strokes or three revolutions. This cycle is as follows :

1. First out-stroke drawing in charge.

2. First in-stroke compressing charge.

3. Second out-stroke following ignition and explosion, with expansion of the hot gases and performance of work.

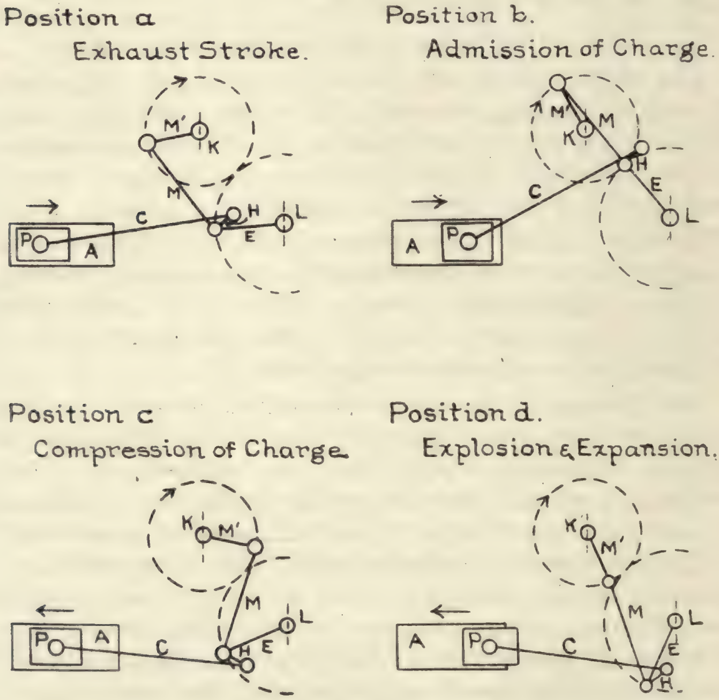
4. Second in-stroke, discharge and exhaust of products of combustion.

5. Third out-stroke drawing in pure air to completely expel the products of combustion.

6. Third in-stroke discharging air into atmosphere.

The addition of the last two strokes is for the purpose of thoroughly cleaning the cylinder from the products of combustion of the previous explosion, so that the next charge will not be diluted and weakened by these inert products. Being made double acting, the Griffin engine was not subject to the difficulty of regulating the speed caused by the infrequency of impulses in an engine employing this cycle in a single-acting cylinder, and had quite a success. But it is no longer made as a six-cycle engine, the later types using the Beau de Rochas Cycle in a double acting cylinder.

The Atkinson cycle engine was designed to secure a greater degree of expansion of the products of combustion than is possible in engines of the Otto type, in which all of the strokes are of the same length, and expansion cannot go beyond the original volume of the charge before compression, and also to make the expansion more rapid. The engine employs the Beau de Rochas Cycle in a single cylinder open at one end, but owing to the manner in which the piston is connected to the motor crank by a series of rods, links and levers, instead of by the usual connecting rod, the whole cycle is completed during one revolution of the crank, and the admission and compression strokes are much shorter than the expansion and exhaust strokes. By this difference in the length of the strokes a greater degree of expansion than is possible in the ordinary type is secured, and the products of combustion are very completely expelled from the cylinder without the necessity of drawing in and expelling a charge of air. It is almost impossible to give a clear idea of the link and toggle motion by which these results are secured with one piston in a cylinder open at one end, without the aid of diagrams, and therefore those given on the cut and the following description of them are taken from "A Text Book on Gas, Air and Oil Engines," by Bryan Donkin, M. Inst. C. E.: "The distinguishing feature of the Atkinson cycle engine is the link and toggle motion shown in four positions. A is the cylinder and P the piston, C is the connecting rod to the small vibrating link, H, which, through E, is joined to the fixed point, L. M is the lever connecting through the crank, M_1, to the crank shaft, K. Position (a) shows the end of the exhaust stroke, when the piston is at the inner dead point. The piston moves out, drawing in the charge, and the lever, M, rises, carrying the link, H, with it. At (b) the crank has performed nearly a quarter of a revolution, and H and M are in their highest positions. The energy of motion carries M



ATKINSON CYCLE ENGINE.

and M_1 round, forcing down H (position c) and the piston moves in, compressing the charge, but not to the point from whence it started. The clearance space left at the end of the cylinder is slightly larger than before, and the charge is driven into it at a pressure of about 45 lbs. The proportion of compression to admission is as 4 to 5. At the end of this stroke, when the crank has performed another quarter revolution, the pressure forces the gases up the red hot tube, and ignition follows. The piston is driven out to the extreme limit of the cylinder, M and H are both in their lowest positions (d), and the crank has completed three-quarters of a revolution. The exhaust stroke following is longer than the expansion, since the piston moves in to the extreme end of the clearance space. M and H are raised, the crank completes its revolution, the products of combustion are thoroughly discharged, and the cylinder cleared for the next admission stroke. In the "Cycle" engine the ratio of cylinder volume utilized for compression is 2.5, and for expansion, 4.3. The lengths of the four unequal piston strokes are: First forward stroke (admission), 6.3 inches; first return stroke (compression), 5.03 inches; second forward stroke (expansion), 11.13 inches; second return stroke (exhaust), 12.43 inches. These dimensions are for an engine of 2 H. P., nominal."

This engine also proved economical of gas, as was shown by tests made in competition with other engines, among which was the Otto, but its manufacture has been abandoned.

Complaints.

282. If you were sent to a house to investigate a complaint of "poor gas," how would you proceed to determine the cause of the trouble?

Ans. It is assumed in this answer that it is known that the main in the street and the service into the house are both of sufficient size to insure a proper pressure at the head of the service at all times if there is no stoppage in the service, that the house-piping is of the proper size and that the burners are in good order.

First determine, either by inquiry from the consumer or by investigation, the nature and location of the trouble. If it is general, that is, occurs all over the house, the cause must be sought in the service, meter, or the riser between the meter and the first branch pipe. If it is confined to one floor or one room, it is only necessary to examine the portion of the system which supplies the floor or room.

Poorness of light due to a uniform low pressure without fluctuation indicates the existence at some point of an obstruction formed by solid matter. A quick sharp jumping of the flame shows an accumulation of liquid at some point, and a slow rise and fall in the size of the flame which takes place at comparatively long and regular intervals is a sign that the meter is overloaded or else sticks at some point. If intelligent information as to the above points can be obtained from any of the inmates of the house, the procedure can be governed accordingly. If this information cannot be had, it will be necessary to secure it by lighting burners in various parts of the house and in sufficient number to test the steadiness of the delivery of the meter, and then determine from observation of the flames the probable cause of the trouble.

If the trouble is located on a particular floor or in a particular room, examine and clean the burner keys and the bracket swings, and if this does not remedy it explain to the consumer just where you think the stoppage is located and tell him to call in a plumber and have it removed, but do not take off the chandeliers or brackets.

If the trouble is general and seems due to an obstruction of solid matter, take out the plug in the tee where the service comes through the cellar wall and determine whether the service is clear, either by observing the amount in, and the force with, which the gas escapes through the open end of the tee, or else by blowing into the service with the lungs. If it is found not to be clear, try to clear it by the use of a wire and an air-pump, or by the use of gasolene or naphtha followed by the pump. If the service is clear, examine the inlet connection of the meter, and then if necessary the outlet connection, being particularly careful to see that these connections have not been flattened in any place so as to shut off the flow of gas.

When an accumulation of liquid at some point is suspected, test the service as above. The presence of water can be readily detected by the intermittent flow of gas, as well as by the gurgling noise made by the gas as it bubbles through the water. If water is found, blow it out with the pump. If the service is clear, take out the meter drip plugs to see if any water has condensed and lodged in the meter drips.

Test the meter also by leaving it connected on the inlet and taking off the outlet connection, so as to allow the gas a free passage through it, and note the rate and the steadiness with which it flows. This meter test should also be made where an obstruction of solid matter is suspected but cannot be located in the service or the meter connections.

A general trouble that cannot be found in either the service, meter, or meter connections must be in the house piping, and if the stoppage cannot be removed by running a wire up the main riser or by blowing out the exposed pipes in the cellar, locate it as closely as possible, tell the consumer where you believe it to be and advise him to call in a plumber to clean it out. If water is found in the service, notice should be given the main laying department so that the service can be taken up and relaid to a proper grade.

283. A complaint of a leak of gas is received from a consumer. Assume that it is your duty to investigate the complaint and tell how you would handle the job.

Ans. The person investigating a complaint of a leak of gas should, after reaching the house and making known his identity and errand, obtain from the occupants all the information possible as to the size and location of the leak. If they can give definite information it can be acted upon, but failing such information a thorough examination of all the fixtures and piping will be required.

When the leak is noticeable in one room only, the keys of the fixtures in that room should be examined to see that all are shut-off and that there are no leaks around them. Finding the keys tight, the joints between different parts of the fixtures and between these and the pipe outlets should next be investigated. In every case the examination should be made by smelling at the suspected points, or, in case the sense of smell is deficient, by means of soapy water. In no case should a light be used, as it is dangerous. Moreover, even very small leaks can be located by smelling or by soapy water more quickly and accurately than by the use of a light. Never strike a match or attempt to light a leak after it has been found.

Where the smell of gas is noticeable more or less all over any one floor, the leak cannot be above this floor and should be sought below it. In such a case it is well to start the search in the cellar, examining the end of the service, the meter and its connections and all exposed piping, and, failing to find in any of these a leak sufficient to produce the smell noticed, the points at which the water pipe and sewer enter the cellar, and also any open joints in the masonry of the walls through which gas might be coming in from a leak outside the house. If gas is found to be coming in from outside, steps should be at once taken to have the leak located and stopped. The nearest telephone should be used for communicating with the office if necessary. If no clue is found in the cellar the examination should be continued on the floors above until the leak is found or until all the fixtures and exposed pipes have been gone over. If the leak cannot be located on the premises, investigations should be made of the adjoining properties and the search continued until the leak is found.

When no leak can be located in the exposed work, its location in the concealed piping can often be closely approximated by smelling at the openings around sliding doors and along the baseboards.

Having located the leak, if it is inside the house, it is well to determine the rate of leakage by means of the test hand on the meter, it having been made certain that no gas is being used at the time. This done, the leak, if it can be gotten at and is such that it cannot be immediately repaired permanently, should be stopped temporarily with soap. If it is around the service, meter or meter connections, the consumer should be told that it has been stopped temporarily and that the company will have it fixed permanently as soon as possible. This should also be done for a leak in a fixture or in exposed house-piping when the gas company does such work, otherwise the consumer should be told that it is necessary for him to have a gas-fitter attend to it.

If the leak is in the house and is bad but cannot be located, or if located cannot be gotten at, the gas should be shut off at the curb cock, when there is one, or else at the meter. The fact that the gas has been shut off should be at once communicated to the office, using telephone if necessary, so that an official letter can be sent to the consumer explaining why the gas is off and what the consumer must do to get the gas turned on again. If the leak is outside the house and is bad, the cellar windows, and if necessary the first floor windows as well, should be opened for ventilation and the consumer instructed to keep them open and avoid the use of lights until the leak has been found and repaired. When the leak is small the gas need not be shut off in case of inability to locate and repair it, but the consumer should be instructed to get a gas-fitter to attend to it or told that the company will take further steps to stop it, as the case may be. Such steps would probably include the use of an air pump and ether to locate the leak, and the opening of the floor or wall to afford access to it.

If, on calling to investigate a leak, it is found impossible to gain access to the premises and there is an odor of gas coming from the keyholes, window joints, etc., the gas should be immediately turned off at the curb cock, if there is one, and, if the house is apparently occupied, the police authorities notified. If unoccupied, access should be gained to the premises by securing the keys from the custodian. In either case, the office should be notified at once, by telephone.

If a leak is found to be dangerously bad, street help should be secured at once from the office. The occupants of all the premises in which the gas may be finding its way should be notified, and the houses ventilated.

If, when answering a complaint, a careful search reveals no leak, the occupants should be questioned further. Occasionally the statement is made that the odor of gas is noticed at a particular time of day, or during a certain condition of the weather. An appointment should be made to call at such a time in order that the consumer may be completely satisfied.

When an escape of gas has caused sickness, or an explosion or fire has occurred, the office should be notified at once, by telephone.

284. A consumer who has received an unusually large bill for gas consumed during the preceding month complains that it is not correct. Assume that it is your duty to investigate the complaint and tell how you would handle the job.

Ans. The first step in the investigation of a complaint of an unusually large bill for gas should be to check the work done in making out the bill to see that no mistake has been made either in copying the meter readings, or in calculating the amount of money from the quantity of gas. Finding everything correct in this respect, the reported meter reading should be verified by at once reading the meter again and comparing the rate of consumption indicated by the difference between this reading and the last one on the bill in question with the rate shown by the bill.

If no error appears here, the question whether the consumption complained of was unusually large should be settled by examining the record of the previous bills of the same consumer in the same location for the preceding two years, or if the consumer is a new one, or has recently moved to his present location, the bills of the former consumer in the same house and those of the complaining consumer in his former residence should be looked up. If this examination shows that the bill is little, if any, larger than would be expected from the record of previous years this record should be shown to the consumer and an attempt made to persuade him that the bill was not an abnormal one. In making the comparison of the present and former bills, the bills for the month next preceding that in question should also be included, in order to ascertain whether or not through an under reading of the meter at the end of the preceding month the bill for that month had been made small at the expense of that for the month in question. If the examination showed that it was unusually large, or the consumer could not be convinced that it was not, an endeavor should be made to find out either by questioning the consumer or members of his family, or by investigation in other directions, whether there was not some good reason, such as the installation of some new gas appliances, the presence of guests in the house for a week or two, the giving of a reception or other entertainment, or the occurrence of sickness in the family, which explained why more gas than usual should have been burned that month. If care is not taken to have each meter read as nearly as possible on the same date each month, and the date on which each statement is taken is not given on the bills and on the records, it should be made certain that the bill in question did not cover an unusually long period of time. If any reasons for an abnormal bill are brought to light in this way they should be reported to the consumer and an endeavor made to satisfy him that the bill was correct.

If no reasons are found, the person investigating should try to form an opinion of his own as to whether the bill was an unreasonable one for the house by an examination of the number and character of the burners and gas appliances that are used. Failing to discover in these ways any cause for an extra consumption of gas, the meter should be removed and tested. If the test shows the meter to be correct, or so little in error as not to account for the extra size of the bill, the pressures at the house should be investigated in connection with the character of the burners and appliances used, and if the burners and other appliances are not adapted to burn gas economically under the existing pressures, an offer should be made to the consumer to substitute new burners, and to adjust the other gas-consuming appliances to suit the existing pressures.

In the event of not discovering any reason for an abnormal bill either in the meter, which should be very carefully examined as to the condition of its gearing, diaphragms, etc., if there be the slightest doubt that the prover test does not indicate the true condition of affairs, or in the conditions existing at the house, the payment of the bill should be insisted upon, unless it is thought that its size was so unreasonable from the consumer's standpoint that it would be bad policy to force its entire payment. In such a case a certain portion should be remitted.

In all dealings with the consumer during the investigation he should be treated in such a way as to make him feel that it was thought that he was sincere and might have some reason for his complaint, without committing the gas company to the acknowledgment that there was any error until the matter had been investigated.

285. Give a description of a "Complaint Meter," and state the purposes for which it is useful.

Ans. A "Complaint Meter" is a meter which will record the time and the rate of speed at which gas passes through it, and is essentially an ordinary dry meter equipped with a mechanism for making such a record.

This mechanism is placed in a box built of tin on top of the regular meter case and provided with a hinged cover. It consists of a cylinder caused to revolve by clockwork and a pen point so placed as to make a continuous line upon a record sheet wrapped around the cylinder. The latter is carried upon a threaded shaft, which imparts longitudinal motion to the extent of about $\frac{1}{4}$ in. for each complete revolution, and is caused to revolve by a pinion engaging with a gear wheel forming one end of the cylinder. The pinion must be made long enough to engage the wheel over the full length of travel of the cylinder. The clockwork drives it at such a rate as to produce one complete revolution of the cylinder in twelve hours and will run, with one winding, for full seven days. The pen point is carried at the upper end of an arm suspended on a pivot placed above its centre of gravity so that it hangs vertically with its lower end almost touching the shaft carrying the test hand of the meter dial, and is free to swing on the pivot. On the shaft named is fixed a cam which strikes the vertical arm and pushes it to one side once during each revolution of the test hand.

The meter having been substituted for, or placed in tandem with, the regular consumer's meter in any location, a record sheet printed and ruled to show the days and hours for a week is placed upon the cylinder, and the clockwork wound up and started with the cylinder in the proper position to have the pen, furnished with a supply of ink, touch the sheet at the point corresponding to the time at which the start is made. As long as no gas passes through the meter the pen will not move and will make a straight line on the sheet, but when gas is being consumed the revolution of the test hand will cause the cam on its shaft to come into contact with the lower end of the arm carrying the pen and push it to one side so that the pen is deflected and makes a short mark on the paper at right angles to the line traced by it when at rest. Since one of these marks is made for each revolution of the test hand, each one indicates the passage of the amount of gas corresponding to one revolution of this hand (in 5-light meters this is 2 cu. ft.), and the rate at which gas is being consumed at any time is determined by multiplying the number of marks made in a given interval by the quantity represented by each one.

The charts obtained from a meter of this kind show clearly at what hours and, for each interval of time, exactly the rate at which gas passes through the meter, and makes it possible to give to the consumer information that in a great majority of cases will satisfy him of the correctness of bills about which he has complained, and also post him as to small leakages and the consumption of gas at times and for purposes about which he knows nothing. They can also be used to determine the maximum demand of any given consumer, or, by setting one in each house along a certain piece of main, the total maximum demand on that piece. The latter information is valuable as giving data from which to calculate the size of pipe that should be used in laying a new main under similar conditions.

SECTION V.—CHEMICAL.

286. Give a brief description of calcium carbide, and of acetylene, and their properties.

Ans. Calcic carbide, or carbide of calcium, as it is popularly called, is a heavy, hard, gray crystalline substance, composed, by weight, of 40 parts of calcium and 24 parts of carbon. Its specific gravity is 2.262. It has a strong affinity for water, and when exposed to the atmosphere absorbs moisture, giving up acetylene gas. (See equation below.)

Calcic carbide is formed by the union of calcium and carbon, fused in the heat of the electric arc. The calcium is used in the form of quicklime, and the carbon as powdered coke, coal or charcoal.

The reactions occurring in the production of calcic carbide are:

0.875 lb. quicklime + 0.5625 lb. carbon = 1 lb. calcic carbide +
$CaO + 3C = CaC_2 +$
0.4375 lb. carbon monoxide.
CO

Acetylene gas is, chemically, an unsaturated hydrocarbon of the series $C_n H_{2n-2}$. Its formula is $C_2 H_2$, and it is composed by weight of 24 parts carbon and 2 parts hydrogen.

It is a colorless gas. When pure it has a sweet, ethereal odor, but impurities give the commercial gas a strong, garlic-like odor. Its specific gravity is 0.91. Its weight per cubic foot is 0.07 lb. Water at 60° F. will absorb about its own volume of $C_2 H_2$. It burns with a highly luminous flame. Its illuminating power is approximately 240 candles for five cubic feet.

When unmixed with other gases or with air, it must, in order to develop its full illuminating value, and prevent smoking, be burned through small, flat flame burners. It is very rich in carbon, and the flame smokes when large burners are used.

It is present in coal gas to a fraction of one per cent., and in a somewhat higher proportion in carburetted water gas. It is formed during the incomplete combustion of illuminating gas. This occurs when the flame of a Bunsen burner "flashes back," the gas burning within the burner.

The present important source of acetylene is calcic carbide. When water is brought in contact with calcic carbide acetylene gas and quicklime are formed, according to the following equation:

1 lb. calcic carbide + 0.5625 lb. water = 1.15625 lb. calcic
$CaC_2 + 2H_2O = Ca(OH)_2$
hydrate + 0.40625 lb. acetylene
$+ C_2H_2$

One pound of pure calcic carbide produces 0.406 lb., or 5.8 cubic feet acetylene.

Acetylene burns to water vapor and carbon dioxide.

287. What is oxidation? What is combustion?

Ans. "Chemically considered, oxidation and combustion are identical, being in each case the combination of oxygen with another element or elements.

"When the union with oxygen takes place rapidly with the production of light and heat, the process is called 'combustion.' This is seen in the burning of coal or wood.

"On the other hand, 'oxidation' is accomplished slowly and gradually, and usually without any perceptible increase in temperature, as in the rusting of iron."

Combustion may be scientifically defined as a union of any two or more elements with evolution of light and heat, but in general the word is defined as above.

288. What is meant by the atomic or combining weight of a substance? What use is made of this weight?

Ans. The atomic or combining weight of a substance is the ratio between the weight of an atom of the substance and that of an atom of hydrogen, the weight of the hydrogen atom being taken as unity, since it is the lightest of all known atoms. The atomic weights of the various elements do not, therefore, represent any absolute weights, but merely the number of times that the atoms of the respective elements are heavier than the atom of hydrogen.

Atomic weights are useful in calculating the proportionate weights in which various substances enter into combination with each other, or into any chemical reaction. Since all chemical compounds are formed by the combination of atoms or multiples of atoms of the various elements, the weights of the different elements in any compound must always be proportional to their atomic weights, and therefore knowing the atomic or proportionate weights of the atoms of the various elements in any compound, the proportionate weights of each of the elements contained in the compound, and of the compound itself, can be determined as soon as the formula of the compound, that is, the number of atoms of each element contained in it, is known. The same thing is true of the molecular weights of compound substances, since such substances always enter into chemical reactions in weights proportional to their molecular weights.

As an instance of the use of atomic weights, the formation of carbon dioxide, CO_2, may be taken. This gas is formed in the combustion of carbon, C, by the union of carbon and oxygen, O. The equation of the reaction between the two substances is $C + O_2 = CO_2$, that is, one molecule of carbon, consisting of one atom, unites with one molecule of oxygen, consisting of two atoms, to form one molecule of carbon dioxide, consisting of one atom of carbon and two of oxygen. The atomic weight of carbon is 12 and that of oxygen 16, so the proportion by weight in which they unite is 12 of carbon to 32 of oxygen. That is, 12 lb. of carbon unite with 32 lb. of oxygen to form 44 lb. of carbon dioxide, and, whatever the weight of carbon, the weight of oxygen required for its combustion and the weight of carbon dioxide produced can be easily found from the above proportions.

In the same way the proportional weights in which any substances enter into chemical combination are determined from their atomic or molecular weights.

289. The atomic weights of various elements are as follows:

Hydrogen, H	1
Oxygen, O	16
Sulphur, S	32
Carbon, C	12
Nitrogen, N	14
Iron, Fe	56
Calcium, Ca	40

Give the molecular weights and the proportion by weight in which the various elements are contained in the following substances :

Carbon Monoxide	CO
Ammonia	NH_3
Sulphuric Acid	H_2SO_4
Calcic Hydrate or Slaked Lime,	$Ca(OH)_2$
Sulphuretted Hydrogen	H_2S
Sulphate of Ammonia	$(NH_4)_2SO_4$
Ferric Hydrate, or Hydrated Sesquioxide of Iron	$Fe_2O_3 . H_2O$

Ans. Each molecule of carbon monoxide, CO, contains one atom of carbon, C, and one of oxygen, O, and its weight is equal to the sum of the weights of these two atoms. Therefore, its molecular weight is equal to the sum of the atomic weights of carbon, C, and oxygen, O, or to $16 + 12 = 28$. This shows that 16 lb. of oxygen, O, unite with 12 lb. of carbon, C, to form 28 lb. of carbon monoxide, CO, or, putting it in another way, that carbon monoxide, CO, contains $\frac{16}{28}$ or 57.14% by weight of oxygen, O, and $\frac{12}{28}$ or 42.86% by weight of carbon, C.

Working in the same way the various substances named are found to possess the following molecular weights and compositions by weight :

Substance	Molecular Weight	Parts by Weight in which the Elements Enter into the Compound
NH_3	$14 + 3 = 17$	14 of N and 3 of H
H_2SO_4	$2 + 32 + 64 = 98$	2 of H, 22 of S and 64 of O
$Ca(OH)_2$	$40 + 2(16 + 1) = 74$	40 of Ca, 32 of O and 2 of H
H_2S	$2 + 32 = 34$	2 of H and 32 of S
$(NH_4)_2SO_4$	$2(14+4)+32+64=132$	28 of N, 8 of H, 32 of S and 64 of O
$Fe_2O_3 . H_2O$	$112+48+2+16=178$	112 of Fe, 64 of O, 2 of H

Substance	Percentage Composition by Weight
NH_3	82.35% N, 17.65% H
H_2SO_4	2.04% H, 32.65% S, 65.31% O
$Ca(OH)_2$	54.06% Ca, 43.24% O, 2.70% H
H_2S	5.88% H, 94.12% S
$(NH_4)_2SO_4$	21.21% N, 6.06% H, 24.24% S, 48.49% O
$Fe_2O_3 . H_2O$	62.92% Fe, 35.96% O, 1.12% H

290. What are the products of the complete combustion of each of the following substances?

Carbon, C	Methane or Marsh Gas, CH_4
Carbon Monoxide, CO	Ethylene or Olefiant Gas, C_2H_4
Hydrogen, H_2	Ethane, C_2H_6
Benzene, C_6H_6	Acetylene, C_2H_2

Give in each case the weight of the products produced by the combustion of one pound of the substance, and in the case of gases give also the volume of each of the products produced by the combustion of one cubic foot of the substance.

Ans. The products of combustion of the various substances named when burned in oxygen, O_2, are,

Substance		Products of Combustion
Carbon	C	Carbon Dioxide, CO_2
Carbon Monoxide	CO	" " "
Hydrogen	H_2	Water Vapor, H_2O
Marsh Gas	CH_4	Carbon Dioxide, CO_2, and Water Vapor, H_2O
Olefiant Gas	C_2H_4	" " " " " " "
Ethane	C_2H_6	" " " " " " "
Benzene	C_6H_6	" " " " " " "
Acetylene	C_2H_2	" " " " " " "

When substances are burned in air it is usual to consider the nitrogen, N_2, which is mixed in the air with the oxygen used, as being also a product of the combustion. To the products as given above should, therefore, be added in each case this nitrogen.

The weights of the products produced are found as follows:

When carbon is burned, each atom combines with two atoms of oxygen, forming carbon dioxide, CO_2. The atomic weight of carbon being 12 and that of oxygen being 16, the molecular weight of carbon dioxide, each molecule of which contains one atom of carbon, and two atoms of oxygen, is $12 + 32 = 44$. Hence, 12 lb. of carbon will yield upon combustion 44 lb. of carbon dioxide and 1 lb. will yield $\frac{44}{12} = 3.67$ lb. of carbon dioxide. Since air contains 3.31 times as much nitrogen by weight as it does oxygen, the weight of nitrogen mixed in the air with the amount of oxygen, 2.67 lb., required for the combustion of 1 lb. of carbon will be 2.67 ×

$3.31 = 8.84$ lb. The products of the combustion in air of 1 lb. of carbon are, therefore, 3.67 lb. of carbon dioxide and 8.84 lb. of nitrogen.

The atomic weight of hydrogen is 1. Two atoms of hydrogen combine with one atom of oxygen to form a molecule of water vapor, the molecular weight of which is $2 + 16 = 18$. Two pounds of hydrogen thus yield upon combustion 18 lb. of water vapor, and 1 lb. will yield 9 lb. of water vapor. There will be mixed in the air with the amount of oxygen, 8 lb., required for the combustion of 1 lb. of hydrogen, $8 \times 3.31 = 26.48$ lb. nitrogen. The products of the combustion in air of 1 lb. of hydrogen are, therefore, 9 lb. of water vapor and 26.48 lb. of nitrogen.

The combustion of marsh gas, or methane, CH_4, produces both carbon dioxide and water. A molecule of marsh gas contains one atom of carbon and four of hydrogen and has a molecular weight of $12 + 4 \times 1 = 16$. In every 16 lb. of marsh gas there will thus be 12 lb. of carbon and 4 lb. of hydrogen, or each pound will contain 0.75 lb. of carbon and 0.25 lb. of hydrogen. It has been shown above that each pound of hydrogen burns to 9 lb. of water vapor, and that each lb. of carbon burns to 3.67 lb. of carbon dioxide. Hence, the products of combustion of 1 lb. of marsh gas will be $0.75 \times 3.67 = 2.75$ lb. of carbon dioxide and $0.25 \times 9 = 2.25$ lb. of water. The amount of the oxygen drawn from the air is $2 + 2 = 4$ lb., so the weight of nitrogen to be included with these products will be $4 \times 3.31 = 13.24$ lb.

The nature and weight of the products of combustion of the other hydrocarbons named can be determined in a similar manner to that employed above for marsh gas.

The volume of each of the products obtained by the complete combustion of one cubic foot of any given gas can be obtained very readily from the equation for the chemical reaction that takes place, since equal volumes of any gases contain equal numbers of molecules, or in other words the molecules of all gases have the same volume and the volume in which gases combine with each other are proportional to the number of molecules of each gas which enter into the reaction.

In the case of hydrogen the reaction by which combustion takes place has the following equation, $2\ H_2 + O_2 = 2\ H_2O$. This shows that two molecules, or two volumes, of hydrogen combine with one molecule, or one volume, of oxygen to form two molecules, or two volumes, of water vapor. Therefore the complete combustion of 1 cu. ft. of hydrogen will require 0.5 cu. ft. of oxygen and will produce 1 cu. ft. of water vapor. Since air contains 3.77 parts of nitrogen to one of oxygen by volume there will be $\frac{3.77}{2} = 1.89$ cu. ft. of nitrogen mixed with the oxygen required, and the volume of the products of the complete combustion in air of 1 cu. ft. of hydrogen will be 1 cu. ft. of water vapor and 1.89 cu. ft. of nitrogen.

In the case of carbon monoxide the equation according to which combustion takes place is $2\ CO + O_2 = 2\ CO_2$, or 1 cu. ft. of carbon monoxide will combine with 0.5 cu. ft. of oxygen and form 1 cu. ft. of carbon dioxide. The volume of nitrogen mixed with the oxygen will be the same as in the case of hydrogen.

The volumes of the products of combustion of each of the other gases named in the question can be worked out in the same way.

For convenience the results of all the determinations both for weight and volume are given below in tabular form.

Name of Substance	Weight of Each Element in 1 lb. of Substance			Weight of Products produced by the Combustion of 1 lb. of Substance, the Nitrogen mixed in air with the Oxygen required for Combustion being considered as a Product of Combustion.			Volume of Products produced by the Combustion of 1 cu. ft. of Substance, Nitrogen being included as before.		
	C	H_2	O_2	CO_2	H_2O	N_2	CO_2	H_2O	N_2
Carbon C	1.000			3.67		8.84			
Carbon Monoxide..CO	0.429		0.571	1.57		1.89	1.0		1.89
Hydrogen ....H_2		1.000			9.00	26.48		1.0	1.89
Marsh Gas.. .. . CH_4	0.750	0.250		2.75	2.25	13.24	1.0	2.0	7.54
Olefiant Gas........C_2H_4	0.857	0.143		3.14	1.29	11.35	2.0	2.0	11.31
Ethane.. .. ..C_2H_6	0.800	0.200		2.94	1.80	12.38	2.0	3.0	13.20
Benzene .... C_6H_6	0.923	0.077		3.39	0.69	10.19	6.0	3.0	28.28
Acetylene . .. C_2H_2	0.923	0.077		3.39	0.69	10.19	2.0	1.0	9.43

291. A pound of a certain coal contains 14 ounces of carbon and 0.5 ounce hydrogen. What would be the products of its complete combustion, and how much would each product weigh? How many "heat units" would be developed by the complete combustion of this carbon and hydrogen? Give your calculations.

Ans. According to the answer to question No. 290, the product of the complete combustion of carbon is carbon dioxide, in an amount weighing 3.67 times as much as the carbon. Therefore, 14 ounces of carbon will burn to $14 \times 3.67 = 51.38$ ounces of carbon dioxide.

According to the same answer, the complete combustion of hydrogen produces water vapor in an amount weighing 9 times as much as the hydrogen. Therefore, 0.5 ounce of hydrogen burns to $0.5 \times 9 = 4.5$ ounces of water vapor.

So the products of the combustion of coal containing 14 ounces of carbon and 0.5 ounce of hydrogen will be 51.38 ounces of carbon dioxide and 4.5 ounces of water vapor, if the sole combustibles in the coal, as understood by the problem, are carbon and hydrogen, and these burn in air.

One pound of carbon, in burning, develops a heating power equivalent to 14,647 heat units. Fourteen ounces, or $\frac{7}{8}$ of a pound of carbon, will develop, in burning, $\frac{7}{8}$ of 14,647, or 12,817 heat units. One pound of hydrogen, burning to water vapor, develops 52,038 heat units and 0.5 ounce or $\frac{1}{32}$ of a pound will therefore develop, in burning, $\frac{1}{32}$ of 52,038, or 1,626 heat units. The total heating power developed by the combustion of this coal will therefore be $1,626 + 12,817$, or 14,443 heat units. The actual amount of heating power developed would be somewhat less, because a certain amount of the heating power of the hydrogen and carbon would be consumed in breaking up the chemical combination in which the hydrogen and carbon exist in coal before these elements could combine with oxygen to form carbon dioxide and water vapor.

292. What is spontaneous combustion and in what part of a coal gas works is it most apt to occur?

Ans. Spontaneous combustion is combustion which is caused not, as is ordinarily the case, by the exposure of combustible matter to an outside source of heat of intensity and capacity sufficient to heat the combustible to the temperature of ignition, but by a rise in temperature produced by reactions taking place either between two or more of the different substances of which the combustible matter is composed or between these substances and the oxygen of the surrounding air. In other words it is combustion which is brought about without the application of fire, or of intense heat from an outside source.

Spontaneous combustion can only take place under conditions which permit of the comparatively rapid oxidation of one or more of the components of a combustible substance, and at the same time confine the heat produced by this oxidation to such an extent that it will produce local heating up to the temperature of ignition.

In gas works spontaneous combustion is most apt to take place in the interior of the piles of gas coal stored for future use, but it may also occur as the result of the accumulation of oily waste or rags in a confined space.

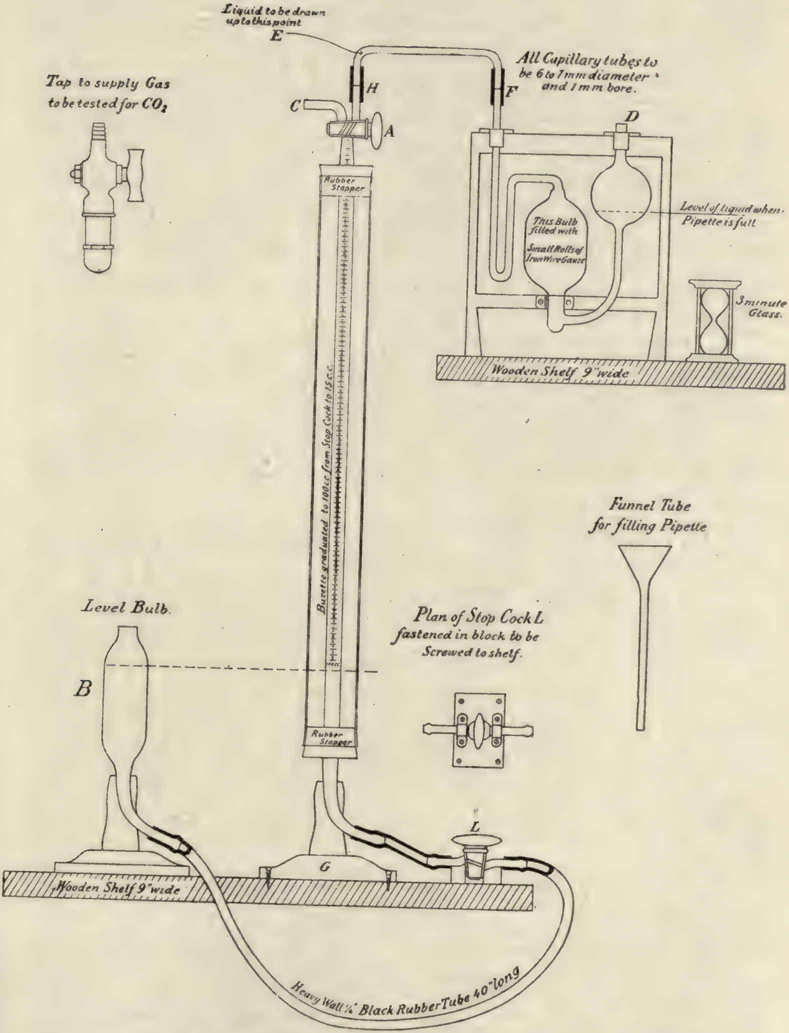
293. How would you make quantitative tests for carbon dioxide and sulphuretted hydrogen in gas? How much by volume of each would you expect to find in coal gas and in carburetted water gas at the inlet to the purifiers?

Ans. "A rapid estimation of the carbon dioxide in gas can be made as follows:

"The apparatus employed is shown in the cut. It consists of a water jacketed graduated burette provided at its lower end with a levelling bulb and communicating at its upper end with the gas supply and the absorption bulb by means of a three-way stop-cock.

"It has a capacity of about 105 c. c. and is graduated in one-fifths c. c. from the stop-cock down to the 100 c. c. mark. The burette is mounted on a solid iron base, which is screwed down to a shelf provided for the purpose close to the gas supply.

"The CO_2 is absorbed by a solution of caustic potash in a pipette filled with rolls of iron wire gauze, which presents a


Liquid to be drawn up to this point
E
All Capillary tubes to be 6 to 7 mm diameter and 1 mm bore.
Tap to supply Gas to be tested for CO_2
H
F
C
A
D
Rubber Stopper
This Bulb filled with Small Rolls of Iron Wire Gauze
Level of liquid when Pipette is full
3 minute Glass.
Wooden Shelf 9" wide
Burette graduated to 100 cc from Stop Cock to 15 c.c.
100 cc
Funnel Tube for filling Pipette
Level Bulb.
B
Plan of Stop Cock L fastened in block to be Screwed to shelf.
Rubber Stopper
L
G
Wooden Shelf 9" wide
Heavy Wall ¼" Black Rubber Tube 40" long

APPARATUS FOR RAPID DETERMINATION OF CARBON DIOXIDE IN GAS.

large surface to the gas. The iron stand holding the pipette is placed on a shelf at a proper height and is connected to the burette by means of a capillary tube with rubber connections. Before making a test, the gas must be freed from sulphuretted hydrogen by passing through an oxide purifier.

"To set up apparatus: Set lower shelf about 36 inches from floor. Screw base of burette, G, firmly to shelf, placing it about half way between wall and edge of shelf. Set upper shelf at such height that the top of capillary, F, on pipette will be level with top of capillary, H, on burette. Fill pipette with potash solution as directed below, and connect parts of apparatus with rubber tubing as shown in drawing. Screw frame of pipette to the upper shelf.

"Loosen upper rubber stopper of water jacket and fill with clear water. Use distilled water if possible, as it will remain clear and free from annoying air bubbles.

"Saturate some clear water, preferably distilled, by allowing gas to bubble through, and with it fill level bulb, B, letting water run into burette as well.

"To prepare solution: Dissolve ¼ lb. of caustic potash in a half pint of water, distilled if possible.

"To fill pipette: With capillary of pipette disconnected from connection at F, pour the solution through funnel tube into pipette at D, until the round bulb is about one-quarter full. Then connect pipette and draw the solution up into capillary as directed below. When the cylindrical bulb is completely filled, the round bulb should remain nearly empty.

"Refill the pipette with fresh solution about once in six months, and carefully note the date of filling on a tag attached to pipette.

"To perform analysis: Open lower stop-cock, L, and turn three-way stop-cock, A, so that burette is open to pipette, then by lowering level bulb, B, draw the potash solution up capillary tube to the point E, just before capillary turns down, and close stop-cock, A. Leaving lower stop-cock open, turn stop-cock, A, till capillary, C, is open to burette, and then by raising level bulb, B, fill burette completely full of water. Close stop-clock, L. Now attach rubber tube to gas supply and allow gas to flow through tube for a moment to displace air; then with gas still flowing attach free end of tube to capillary, C. Open lower stop-cock, L, and draw in gas to the 100 c. c. mark. Close stop-cock, L, and then close stop-cock, A, and detach rubber tube. After three minutes bring the level of the liquid in burette exactly to 100 c. c. mark by raising or lowering level bulb, and close lower stop-cock, L. Open stop-cock, A, to capillary, C, for a moment in order to allow surplus gas to escape. There will now be exactly 100 c. c. of gas in burette, measured under atmospheric pressure. Now open stop-cock, A, to pipette and force gas over into pipette by raising level bulb; draw gas back into burette immediately, letting the potash solution follow up capillary to point E as before, and close stop-cock, A. After three minutes, by raising or lowering level bulb, B, bring the water in burette and level bulb to the same level and close stop-cock, L. Note the point at which the water now stands in burette, and the difference between this reading and the original amount taken will be the CO_2 absorbed.

"NOTE.—See that the stop-cocks are kept well greased. If a stop-cock is found to be stuck, do not apply force to turn it. It may readily be loosened by warming the glass with a cloth dipped in hot water. When apparatus is not in use, the open ends of level bulb and pipette should be closed with corks." (*Adapted from Hempel's Gas Analysis.*)

The amount of sulphuretted hydrogen in illuminating gas can be determined with a portable apparatus for the purpose devised by Mr. C. C. Tutwiler. "To describe the apparatus briefly, it consists of an absorption burette, provided with 3-way glass stop-cocks above and below, the upper one having a connection for the intake of gas and also connecting with a measuring tube surmounting it. This measuring tube is divided into c. c., which are again divided into tenths, holding altogether 10 c. c. of the iodine solution. This solution is carefully prepared so that each c. c. contains 0.0017076 grammes of iodine, which is calculated to absorb 100 grains of H_2S per 100 cubic feet of gas. In the lower part of the burette is admitted about 5 c. c. of a starch solution made by dissolving one gramme of pure starch in 150 c. c. of water. After the burette has been filled in the usual manner with 100 c. c. of the gas to be tested, the iodine is trickled in drop by drop, with frequent shaking of the burette. As long as H_2S is present, the iodine is neutralized by it and does not affect the starch water, but as soon as all the H_2S present in the gas has been neutralized, any excess of the iodine will turn the formerly clear white starch water blue and the operation is then stopped. Readings of the scale on the measuring tube taken before and after the operation give the amount of iodine used to take out the H_2S, and a simple calculation will then give the number of grains of this impurity. If, for instance, we consumed 4.6 c. c. of the solution, we find that we had 4.6 × 100, or 460 grains of H_2S in 100 cubic feet. The possible error with careful manipulation is said not to exceed 10 grains."

The percentages of carbon dioxide and sulphuretted hydrogen found in coal gas at the inlet to the purifiers will vary with the efficiency of the washing and scrubbing apparatus through which the gas passes before reaching this point, since the ammonia in the gas can, by proper treatment, be made to combine with a large proportion of these impurities and remove them from the gas before it enters the purifiers. The percentage of sulphuretted hydrogen will also vary with the percentage of sulphur in the coal from which the gas is made.

Very little has been published in relation to the quantities of these impurities in coal gas made from American coals. In a paper read before the New England Association of Gas Engineers, Mr. Carroll Miller gave some figures which showed that the average amount of sulphuretted hydrogen at the inlet to the purifiers, in coal gas made from Pennsylvania gas coal, at the works under his charge, was about 446 grains per 100 cubic feet. This gas had been passed through rotary scrubbers of the Standard type before going to the purifiers. Dr. E. G. Love has kindly given some figures he obtained in analyzing gas made from a mixture of Pittsburg, Fairmount and cannel coal. The gas at the inlet of the washer scrubber contained 918 grains of H_2S per 100 cubic feet, equal to 1.45% and 785 grains of CO_2 per 100 cubic feet, equal to 0.97%. At the outlet of the washer scrubber, that is, at the inlet to the purifiers, the figures were 254 grains, equal to 0.40%,

H_2S, and 693 grains, equal to 0.85%, CO_2. The gas from coals containing more sulphur, such as most of the West Virginia coals, would, of course, contain more sulphuretted hydrogen. Butterfield gives the amount in well-washed gas made from Durham coal as 500 to 800 grains per 100 cubic feet, equal to from 0.79% to 1.26%. This coal contains from 2½ to 3 times as much sulphur as Pittsburg coal. According to the same authority the carbon dioxide will vary from 700 to 1100 grains per 100 cubic feet, equal to from 0.86% to 1.35%.

In the paper mentioned above Mr. Miller gives the average amount of sulphuretted hydrogen in carburetted water gas made from gas coke and Pennsylvania oil as about 190 grains per 100 cubic feet of gas. As in coal gas the percentage of this impurity will depend on the amount of the sulphur in the coal or coke used, and also upon the amount in the oil. Butterfield gives the figures for English practice as 0.15% to 0.25%. The percentage of carbon dioxide will depend largely on the manner in which the apparatus is run and upon the fuel used, gas made from anthracite containing less than gas made from coke, other things being equal. The amount, assuming careful operation, may be taken as varying from 2.5% to 4.0%.

SECTION VI.—PHYSICAL.

294. Give the weight of a cubic foot of each of the following gases when dry and at a temperature of 60° F. and a pressure of 30 in. of mercury:

Air	
Carbon Dioxide	CO_2
Carbon Monoxide	CO
Marsh Gas	CH_4
Ethylene or Olefiant Gas	C_2H_4
Hydrogen	H_2
Nitrogen	N_2
Oxygen	O_2
Ethane	C_2H_6

Ans. The weights of a cubic foot of the gases named when dry and at a temperature of 60° F. and a pressure of 30 in. of mercury are as follows:

	Grains.	Pounds.
Air	534.5010	0.076357
Carbon Dioxide, CO_2	814.4191	0.11634
Carbon Monoxide, CO	518.2735	0.074039
Marsh Gas, CH_4	296.1563	0.042308
Ethylene or Olefiant Gas, C_2H_4	518.2735	0.074039
Hydrogen,. H_2	37.0195	0.0052885
Nitrogen, N_2	518.2735	0.074039
Oxygen, O_2	592.3127	0.084616
Ethane, C_2H_6	555.2930	0.0793275

(These weights are on the avoirdupois scale.)

295. Define the term specific gravity of a gas. Give the limits between which you would expect the specific gravity of coal gas to vary. Same for carburetted water gas. How do you account for the difference in specific gravity between the two gases?

Ans. The specific gravity of a substance is the ratio between the weight of any given volume of the substance and that of an equal volume of some other substance selected as a standard. In the case of gases the standard commonly employed is atmospheric air, though in chemical work hydrogen is used as a standard. For the purposes of the class the specific gravity of a gas may be defined as the ratio of the weight of any given volume of the gas to the weight of an equal volume of air, the air and the gas being measured and weighed at the same temperature and pressure.

The specific gravity of ordinary coal gas ranges from 0.350 to 0.500, air being 1.000, increasing with the candle power of the gas. The specific gravity of carburetted water gas as ordinarily made ranges from 0.550 to 0.700.

The greater specific gravity of carburetted water gas is due to the fact that it contains on the one hand smaller percentages of hydrogen, which is the lightest substance known, and of marsh gas, also a comparatively light gas (sp. gr. 0.554), and on the other hand larger percentages of the heavier substance, carbon monoxide (sp. gr. 0.969), and of the heavy hydrocarbons (sp. gr. from 0.969 upwards) than does coal gas.

296. What is meant by the term "specific gravity" in the expression: "The specific gravity of coal gas varies from about 0.410 to about 0.475?"

Ans. "It means that the weight of coal gas is 410/1000 or 475/1000 the weight of an equal volume of air at the same temperature and height of barometer. In other words, one cubic foot of coal gas will weigh as much as 410/1000 or 475/1000 of a cubic foot of air, at the same temperature and height of barometer."

297. Using the weights per cubic foot of the various gases given in the answer to question No. 294, and the definition of specific gravity given in the answer to question No. 295, calculate (1) the weight of 1,000 cubic feet of coal gas with a specific gravity of 0.445; (2) the weight of 1,000 cubic feet of water gas with a specific gravity of 0.655; (3) the specific gravity of oxygen (O_2), and (4) the specific gravity of carbon dioxide (CO_2). Give your calculations in each case.

Ans. The specific gravity of a gas is defined in the answer to question No. 295 as the ratio of the weight of any given volume of the gas to the weight of an equal volume of air, the air and gas being measured at the same temperature and pressure. The weight of 1,000 cubic feet of coal gas with a specific gravity of 0.445 will therefore be equal to the weight of 1,000 cubic feet of air multiplied by 0.445. As the weight of 1 cubic foot of air at 60° F. and 30 in. pressure is given in the answer to question No. 294 as 0.076357 lb., 1,000 cubic feet will weigh 76.357 lb. Hence $76.357 \times 0.445 = 33.98$ lb. is the weight of 1,000 cubic feet of coal gas with a specific gravity of 0.445. In the same way the weight of 1,000 cubic feet of water gas with a specific gravity of 0.655 is equal to $76.357 \times 0.655 = 50.01$ lb.

The specific gravity of oxygen according to the definition will be equal to the quotient obtained by dividing the weight of a cubic foot of oxygen by that of a cubic foot of air. The weight of oxygen is given as 0.084616, therefore the specific gravity of oxygen equals $\frac{0.084616}{0.076357} = 1.10816$. In the same way the specific gravity of carbon dioxide is equal to $\frac{0.11634}{0.076357} = 1.52363$.

298. The weight of a cubic foot of dry air at 60° F. and 30 in. barometric pressure is 0.076357 lb. The specific gravity of each of the gases named below is set opposite its name. Calculate the weight of a cubic foot of each gas at 60° F. and 30 in. pressure.

Methane	CH_4	0.55408
Ethylene or Olefiant Gas	C_2H_4	0.96964
Ethane	C_2H_6	1.0389
Carbon Monoxide	CO	0.96964
Carbon Dioxide	CO_2	1.52363
Oxygen	O_2	1.10816
Nitrogen	N_2	0.96964
Hydrogen	H_2	0.06926

Ans. Since the specific gravity of a gas is the ratio between the weight of any given volume of the gas and that of the same volume of air measured at the same temperature and pressure, or, in other words, is the quotient obtained by dividing the weight of a given volume of the gas by the weight of an equal volume of air, the weight of a cubic foot of any gas can be found, the specific gravity of the gas and the weight of a cubic foot of air being known, by multiplying the weight of this volume of air by the specific gravity of the gas.

Thus the weight of a cubic foot of Marsh Gas, CH_4, is found by multiplying 0.076357 (the weight of a cubic foot of air) by 0.55408 (the specific gravity of marsh gas), and is equal to 0.042308 lb. All the weights given below are obtained in a similar manner.

Methane or Marsh Gas	CH_4	0.042308 lb.
Ethylene or Olefiant Gas	C_2H_4	0.074039 "
Ethane	C_2H_6	0.079327 "
Carbon Monoxide	CO	0.074039 "
Carbon Dioxide	CO_2	0.11634 "
Oxygen	O_2	0.084616 "
Nitrogen	N_2	0.074039 "
Hydrogen	H_2	0.005288 "

299. Two samples of illuminating gas have the respective compositions given below. Calculate the weight per 1,000 cubic feet and the specific gravity of each.

	Sample No. 1.	Sample No. 2.
Carbon Dioxide, CO_2	1.6%	2.7%
Oxygen, O_2	0.4	0.7
Ethylene, C_2H_4	4.3	12.8
Carbon Monoxide, CO	8.0	30.7
Hydrogen, H_2	47.0	32.4
Marsh Gas, CH_4	36.0	13.9
Ethane, C_2H_6	0.5	3.0
Nitrogen, N_2	2.2	3.8
	100.0	100.0

Ans. In 1,000 cubic feet of gas having the composition of Sample No. 1, there will be:

16	cubic	feet	of	CO_2
4	"	"	"	O_2
23	"	"	"	C_2H_4
80	"	"	"	CO
470	"	"	"	H_2
360	"	"	"	CH_4
5	"	"	"	C_2H_6
22	"	"	"	N_2

The respective weights per cubic foot being:

CO_2	0.11634	lb.
O_2	0.08462	"
C_2H_4	0.07404	"
CO	0.07404	"
H_2	0.00529	"
CH_4	0.04231	"
C_2H_6	0.07933	"
N_2	0.07404	"

the weights in 1,000 cubic feet are:

CO_2	$16 \times 0.11634 =$	1.86	lb.
O_2	$4 \times 0.08462 =$	.34	"
C_2H_4	$43 \times 0.07404 =$	3.18	"
CO	$80 \times 0.07404 =$	5.92	"
H_2	$470 \times 0.00529 =$	2.49	"
CH_4	$360 \times 0.04231 =$	15.23	"
C_2H_6	$5 \times 0.07933 =$	.40	"
N_2	$22 \times 0.07404 =$	1.63	"

and the total weight of 1,000 cu. ft. of gas is 31.05 lb.

The weight of 1,000 cu. ft. of air is 76.357 lb. and therefore the specific gravity of the gas is $\frac{31.05}{76.357} = 0.406$.

By the same method of calculation it is found that the weight of 1,000 cubic feet of the gas having the composition of Sample No. 2 is 48.72 lb. and its specific gravity is 0.638.

300. Under what conditions will a balloon rise when filled with a gas lighter than air, and how much weight can be

lifted by a balloon filled with 2,000 cubic feet of gas, having a specific gravity of 0.6 ?

Ans. A balloon will rise only when its total weight with all appurtenances is less than the weight of the air displaced by it. The case is, to a certain extent, the same as that of equal volumes of two liquids, which will not mix and have different specific gravities, placed one in each leg of a siphon gauge. The heavier liquid will force up the lighter until its upper surface stands at a level which is higher than the level of the upper surface of the heavier liquid by an amount proportional to the difference in weight between them. In this case a state of equilibrium is soon reached owing to the limited quantity of the heavier liquid present to take the place of the lighter liquid as it is forced up, but with the balloon there is an unlimited supply of air to fill up the spaces successively vacated as it rises, and the ascending motion continues until a height is reached at which, owing to the elevation, the weight of the air displaced has become so much reduced as to be only equal to the weight of the balloon and its attachments. At this height the balloon will float as long as no change is made in its weight, in that of the air per unit of volume, or in the volume of air displaced.

To determine the weight (including, of course, the weight of the balloon itself) that can be lifted by a balloon filled with 2,000 cubic feet of gas having a specific gravity of 0.6, it is assumed that both gas and air are dry and at a temperature of 60° F. and a pressure of 30 in. of mercury, and that the displacement of the balloon is equal to the volume of gas contained in it. The last assumption, while not perfectly accurate, is sufficiently so for all practical purposes. Since a cubic foot of dry air at the temperature and pressure named weighs 0.076357 lb., 2,000 cubic feet will weigh 152.714 lb. The 2,000 cubic feet of gas in the balloon having a specific gravity of 0.6 will weigh 152.714×0.6, and, therefore, the weight of the air displaced will exceed the weight of the gas by $152.714 \times 0.4 = 61.0856$ lb., and the balloon can lift any weight less than this.

301. How much weight (including its own weight) will a balloon containing 1,000 cubic feet lift when filled with pure hydrogen? With a gas of 0.420 specific gravity? With gas of 0.650 specific gravity? Give the calculations you make in obtaining the answers to this question.

Ans. "If a balloon is at equilibrium at the surface of the earth, according to the laws of buoyancy the weight of the balloon and contents is equal to the weight of the air displaced."

Assuming that the air and gas are at a temperature of 60° F., and the barometer is at a height of 30 in. of mercury, 1,000 cubic feet of air weigh 76.36 lb. 1,000 cubic feet of hydrogen (specific gravity 0.0693) weigh $76.36 \times 0.0693 = 5.29$ lb.

If we displace 1,000 cubic feet of air, weighing 76.36 lb., in the balloon with 1,000 cubic feet of hydrogen, weighing 5.29 lb., the balloon will suspend without lifting,

$76.36 - 5.29 = 71.07$ lb., less the weight of the balloon.

1,000 cubic feet of gas with a specific gravity of 0.420 weighs $76.36 \times 0.420 = 32.07$ lb.

Hence the balloon when filled with this gas will suspend without lifting,

$76.36 - 32.07 = 44.29$ lb., less the weight of the balloon.

1,000 cubic feet of gas with a specific gravity of 0.650 weighs $76.36 \times 0.650 = 49.63$ lb.

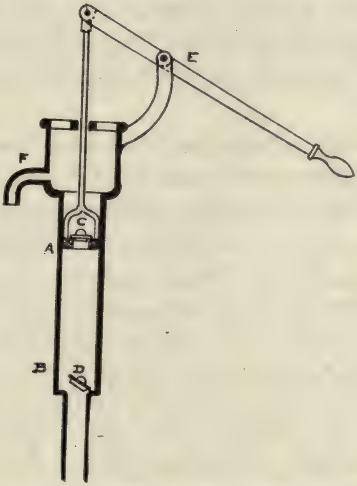
Hence the balloon when filled with this gas will suspend without lifting,

$76.36 - 49.63 = 26.73$ lb., less the weight of the balloon.

The balloon will lift (rise with) any weight less than the above.

302. How does a suction pump "draw" water? Why and how does a hot chimney "draw"?

Ans. A suction pump, as shown in section in the sketch, is provided with a piston, C, and two valves, one in the piston and the other at the point, D, where the suction pipe enters the cylinder, A B. These valves are set in such a manner as to cause water or air to be pushed out of the delivery pipe, F, of the pump and to permit water to enter from the suction pipe into the space below the piston during the up stroke, and also to permit water to travel through the piston from below upwards while preventing any flow of water from the cylinder back into the suction pipe during the down stroke of the piston. Such a pump, therefore, "draws" water by the forcing out from the cylinder of the water, or air, in the space above the piston as this is raised, and thus, by decreasing the amount of water, or air, left to fill the original space, reducing the pressure in the lower part of the cylinder, and in the suction pipe, below that exerted by the atmosphere. The surface of the water outside the suction pipe being thus subjected to a higher pressure than the surface inside this pipe, water is pushed into the pipe and through it into the cylinder of the pump to a height above the outside level dependent upon the amount by which the action of the piston reduces the pressure in the pipe and cylinder below the outside pressure. This pressing up of the water continues as long as the pump is working and delivering water, the space occupied by the water thrown off by each stroke of the piston



SECTION OF SUCTION PUMP.

being filled by water forced in by the excess of pressure on its outer surface. The water is thus moved, not by a pulling force, as is implied by the commonly accepted way of describing the working of a suction pump by saying that it "draws" water, but by a pushing force, each molecule of water being moved along because the pressure behind it is greater than that in front of it.

In the same way the draft of a chimney is caused by a difference of pressure at the base of the chimney, due to the difference between the weight of the column of hot air and products of combustion in the chimney and that of a column of cold external air, of equal height and cross section. The contents of a chimney being all cold, there is no tendency of the air, or the gas within it, to rise or fall. The contents being heated, either from the warm sides of the chimney, or otherwise, expand. A portion of them, by this act of expansion, is forced out of the chimney; the rest of the contents, being expanded, are lighter, by the weight of the amount forced out, than the surrounding atmosphere, and will be displaced by the heavier air pressing for admission at the base of the chimney. A flow through the chimney is thus established, and will be maintained as long as the pressure of the atmosphere at the base of the chimney is greater than the downward pressure of the contents of the chimney.

303. How does an exhauster "draw" gas?

Ans. An exhauster does not "draw" gas in the sense in which the word draw is used to denote the action of pulling objects towards one by means of a string. An exhauster acts by forcing out from the space between its inlet and outlet some of the gas previously occupying such space, and thus reducing the pressure existing within this space below that existing in the pipe leading to the inlet of the exhauster. The difference in pressure thus formed causes a flow of gas from the inlet pipe into the exhauster, and as a consequence a flow of gas through all the apparatus preceding the exhauster so long as the exhauster is running and fresh gas is supplied to take the place of that forced away. The action is thus one of pushing and not of pulling, the gas moving along because at each point of its path the pressure behind is higher than that in front.

304. In delivering water through a pipe laid up a hill, the pressure is greater at the bottom than at the top. Why?

With illuminating gas the pressure is greater at the top. Why?

If the pipe containing the illuminating gas were tightly and rigidly sealed throughout, so that the pressure of the air had no effect upon it, would the pressure within it be greater at the top or at the bottom? Why?

Ans. "In the question the word 'Pressure' is used to express a difference between the pressure of the atmosphere and the pressure within a pipe as measured on a U, or syphon gauge. This is 'pressure' in a gas manufacturing sense, but not *actual* pressure. For when a syphon gauge connected to show the pressure, if any, on the gas in a hydraulic main, shows the water in each leg at the same level, we say there is no pressure in the main, though in truth there is the same pressure in the main and on the water leg of the syphon connected to it, as on the leg open to the atmosphere, that is 'atmospheric pressure,' about 15 lb. per square inch.

"In delivering illuminating gas through a pipe laid up a hill, the action of gravity will cause the *actual* pressure in the pipe to be greater at the bottom than at the top, by the pressure due to the weight of a column of gas of the same vertical height as the hill. But on testing with a syphon, or other similar gauge, the *indicated* pressure will be greater at the top than at the bottom. This apparent paradox is due to the fact that what the syphon gauge indicates is not the actual pressure in the pipe, but is the difference between this pressure and the pressure of the atmosphere at the same level. The atmospheric pressure diminishes with the elevation, so that at the top of the hill it is less than at the bottom by the pressure due to the weight of a column of air of the same height as the hill. This is also true of the gas in the pipe. But as air is heavier than illuminating gas, the atmospheric pressure will diminish more for the same elevation than the pressure of the gas will diminish. Therefore the syphon gauge, which indicates the difference between these pressures, will show a greater difference at the top than at the bottom of the hill.

"In delivering water up a hill the law is the same. The actual pressure in the pipe will be greater at the bottom than at the top by the pressure due to the weight of a column of water of the same vertical height as the hill. The apparent pressure at the bottom, if measured by a syphon gauge, would be the actual pressure less the pressure of the atmosphere, and the same is true of the gauge pressure at the top of the pipe. But as the water is very much heavier than air, the apparent, or gauge, pressure will remain greater at the bottom than at the top.

"If the pipe containing the illuminating gas were tightly and rigidly sealed throughout, the actual pressure at the bottom of the pipe would be the same as at the top, plus the additional pressure due to the weight of a column of gas of the same vertical height as the hill. Gas in a rigidly sealed pipe is free from all outside influence, except that of the attraction of gravitation."

305. A stand pipe 100 feet high is filled with a gas which is lighter than air. The pipe is rigidly and hermetically sealed so that there is no communication between the air outside and the gas inside. Will the absolute pressure of the gas be the same at the top and at the bottom of the pipe? If the pressure is not the same, at which point will it be greater? Give the reasons for your answer.

Ans. The only forces affecting the pressure in a pipe filled with gas and hermetically sealed, are the attraction of gravity and the pressure of the gas itself; that is, the force with which it presses against the sides of the pipe. According to the molecular theory of the composition of matter, this pressure which is exerted against the sides of the containing vessel by a gas is due to the incessant striking against these sides of molecules, each of which is trying to get as far away as possible from the others. In the absence of any disturbing force this pressure is exerted equally in all directions, since all the molecules move with the same velocity and have the same weight, and consequently possess the same energy, and as many travel up as travel down or sideways; and if the gas was imponderable, that is, had absolutely no weight, the pressure would be the same at all points in the height of the pipe. But each molecule has some weight and therefore tends, under the influence of the attraction of gravity, to move downward. This tendency to move downward decreases the velocity of the molecules moving upward, while it increases that of those moving downward, and since the force with which the molecules strike against the sides of the pipe or against each other depends upon the velocity with which they move, the molecules moving upward do not strike as hard, and therefore do not exert as much force or pressure as those moving downward. The difference thus produced between the upward and the downward pressure is in every case equal to the weight of the molecules. As, owing to its weight, each molecule from the top down transmits a greater downward pressure than it receives from the molecules above it, the effect is cumulative, and the total pressure at the bottom of the pipe will be greater than that at the top by an amount equal to the weight of the gas in the pipe, and the pressure per unit of area will be greater at the bottom than it is at the top by an amount equal to the weight of a column of the gas of unit area and of the height of the pipe.

The same reasoning applies to the air in the earth's atmosphere, the pressure of which is greatest at the sea level and diminishes with the height above this level by an amount equal to the weight of a column of air of unit area and a height equal to the elevation of any given point above this level.

306. The answer to question No. 305 shows that in a vertical pipe filled with a gas lighter than air the absolute pressure at the lower end of the pipe is greater than that at the upper end. Will the same relation hold if the pressures shown by syphon gauges are taken, instead of the absolute pressures? Give the reasons for your answer.

Ans. The gauge pressures at the two ends of a vertical or inclined pipe filled with a gas lighter than air do not bear the same relation to each other as do the absolute pressures, the gauge pressure at the top being higher than that at the bottom instead of lower. This difference in gauge pressure between the top and the bottom of an inclined pipe is due to the facts that the syphon gauge does not show the actual pressures, but only the difference between the actual pressures exerted on each leg of the gauge, and that the actual pressure of both the outside air and of gas at rest in a pipe decreases in proportion to their weight as the distance of the point of observation from the centre of the earth increases. The actual pressure of both air and gas at the top of the pipe will be less than at the bottom by an amount equal to the weight of a column of air or gas of unit area and of a height equal to the difference in elevation between the two ends of the pipe. As the gas is lighter than air, the weight of the column of gas will be less than that of the column of air. Therefore, the actual pressure of the gas will decrease less than the actual pressure of the air, and consequently the difference between the actual pressure of the gas and that of the air will increase with an increase in elevation. The lighter the gas, that is, the lower its specific gravity, the smaller will be the decrease in its absolute pressure and the greater the increase in the gauge pressure for any given increase in elevation.

The amount of this increase can be obtained for any particular case by dividing the difference between the weight of a column of air with an area of one square inch and a height equal to the difference in elevation between the two ends of the pipe and that of a column of gas of the same area and height by the weight of a cubic inch of water. For a gas with a specific gravity of 0.700 and for a difference of elevation of 100 ft. between the two ends of the pipe, the calculation would be as follows:

The height of the columns of air and gas will be 100 ft. or 1,200 in., and as the area of the columns is one square inch, the volume will be 1,200 cubic inches. A cubic foot of air weighs 0.076357 lb., and a cubic inch weighs $\frac{0.076357}{1728} =$ 0.00004418. 1,200 cubic inches of air, then, weigh 0.00004418

$\times$ 1,200 = 0.053016 lb. Since the specific gravity of the gas is 0.700, the column of gas will weigh $\frac{7}{10}$ as much as the column of air, and the difference between the weight of the column of air and that of the column of gas will be equal to $\frac{3}{10}$ the weight of the column of air, or to $0.053016 \times 0.3 = 0.0159048$. The weight of a cubic inch of water is 0.036 lb. and the increase in pressure will therefore be $\frac{0.0159048}{0.036} =$ 0.44 in. Thus a gas with a specific gravity of 0.700 will show an increase in pressure of 0.044 in. for each 10 ft. increase in elevation, or an increase of $\frac{1}{10}$ in. for each 22.7 ft. of rise.

In the same way we find that a gas with a specific gravity of 0.600 will show an increase in pressure of 0.059 in. for each 10 ft. of rise, or an increase of $\frac{1}{10}$ in. pressure for each 17 ft. of rise; gas with a specific gravity of 0.500 will show an increase of 0.073 in. for each 10 ft. of rise, or an increase of $\frac{1}{10}$ in. for each 13.6 ft. of rise; gas with a specific gravity of 0.400 will show an increase of 0.088 in. for each 10 ft. of rise, or $\frac{1}{10}$ in. for each 11.3 ft. of rise, and gas with a specific gravity of 300 will show an increase of 0.103 in. for each 10 ft. of rise, or an increase of $\frac{1}{10}$ for each 9.7 ft. of rise.

307. Part of the district supplied by a gas company is 135 ft. higher than the works. The gas distributed is a mixture of coal gas and carburetted water-gas having a specific gravity of 0.550. There is practically no flow of gas through the pipes supplying this portion of the district between the hours of 1 o'clock and 5 o'clock A. M. During this time the pressure at the outlet of the street main governor at the works is $\frac{15}{10}$. What will be the pressure at the 135 ft. level?

Ans. The conditions of the problem are such that the only cause operating to produce a difference in pressure between the street main governor and the high part of the district is the difference in elevation between these two points. As the term pressure is used without any qualification it is understood to carry its commonly accepted meaning of gauge pressure.

According to the answer to question No. 306 the increase in pressure in inches of water, that will be shown by a gas lighter than air on account of a difference in elevation between the points of observation, can be determined in any particular case by dividing the difference between the weight of a column of air with an area of one square inch and a height equal to the difference in elevation between the points and that of a column of the gas of the same area and height, by the weight of a cubic inch of water. In this case the columns of air and gas will be 135 ft. or 1,620 in. high and the weight of a cubic inch of air being 0.00004418 lb. the column of air will weigh $1,620 \times 0.00004418 = 0.07157$ lb. As the specific gravity of the gas is 0.550, the difference in weight between the columns of air and gas will be 0.45 times the weight of the column of air or $0.07157 \times 0.45 = 0.032206$ lb. The weight of a cubic inch of water is 0.036 lb., and therefore the increase in pressure between the governor outlet and a point 135 ft. above it will be $\frac{0.032206}{0.036} = 0.894$ in., or practically $\frac{9}{10}$ and the pressure at the 135 ft. level will, under the given conditions, be $\frac{15}{10} + \frac{9}{10} = \frac{24}{10}$.

308. What is heat?

Ans. Heat (in physics) is that specific form of energy, consisting in an agitation of the molecules of matter, which is capable of producing the sensation of heat. It is measured by the total kinetic energy of such agitation.

Heat is now known to be not a substance, but the energy of molecular motion consisting in the case of a gas of nearly uniform rectilinear motions with sudden changes of direction and velocity when the molecules come near enough to one another; in the case of a liquid of irregular wanderings of its molecules; and in the case of a solid of orbital or oscillatory motions. (Century Dictionary.)

Under this theory that heat is the energy due to a form of motion, changes in the temperature of a body are considered to be due to changes in the rapidity of the motion of the molecules, higher temperature being produced by more rapid motion. As the rapidity of such motion increases it gradually overcomes the mutual attraction of the molecules, and solids are thus changed to liquids and liquids to vapors which finally become gases.

Those students who have not already done so should study the subject of Heat carefully in some good work on Physics, such as Ganot's or Deschanel's, while those who care to go into the subject still more fully should take up Tyndall's Heat as a Mode of Motion and Clerk Maxwell's Theory of Heat.

309. What is a heat unit? What is the value of a British Thermal Unit and of a Calorie?

Ans. In order to be able to express different quantities of heat in comparable terms it is necessary to have some standard or unit of quantity by which to measure these quantities. Such a standard or unit is called a heat unit.

The British Thermal Unit (B. t. u.), the heat unit most largely used by English speaking nations, is the amount of heat required to raise the temperature of one avoirdupois pound of pure water one Fahrenheit degree from the temperature of maximum density of water, which is 39.1° Fahrenheit. The variation in the quantity of heat necessary to raise the temperature of a pound of water one degree is so slight for any temperature between 32° and 212°, that in general the British Thermal Unit may be safely taken as the amount of heat necessary to raise the temperature of one pound avoirdupois of pure water one degree Fahrenheit. Thus we may say that to raise the temperature of 30 lb. of water from 40° to 60° Fahrenheit requires 600 British Thermal Units; for we have raised 30 lb. of water through 20° of temperature, and to raise 30 lb. of water one degree requires 30 British Thermal Units, and to raise the same quantity 20° requires 20 times as much, or 600 British Thermal Units.

A Calorie, the heat unit used in connection with the metric system of weights and measures, is the amount of heat required to raise the temperature of one kilogramme of water one degree centigrade from the temperature of water at its maximum density, or about 4° C. For the reason stated above the Calorie may, in ordinary work, be taken to be the amount of heat required to raise, by one degree centigrade, the temperature of a kilogramme of water at any temperature between 0° C and 100° C. Since a kilogramme equals 2.204 lb. and a degree centigrade equals 1.8° Fahrenheit, a Calorie equals $2.204 \times 1.8 = 3.968$ B. t. u.

310. What is meant by a "unit of heat" or "heat unit?" What is the difference between quantity of heat and intensity of heat?

Ans. In order to be able to express various quantities of heat in comparable terms, it is necessary to have a standard unit of heat.

The standard, or "unit of heat" used in this country, is the "British Thermal Unit," and this is the amount of heat required to raise one avoirdupois pound of pure water one Fahrenheit degree in temperature, from the temperature at which water attains its maximum density, which is 39.1° Fahrenheit. The variation in the quantity of heat required to raise the temperature of a pound of water one degree is so slight for any temperature between 32° and 212°, that in general the heat unit may be safely taken as the amount of heat required to raise the temperature of one pound avoirdupois of pure water one degree Fahrenheit.

By quantity of heat is meant the total amount of heat possessed by a body or involved in any thermal operation. It depends not only on the temperature or change in temperature, but also upon the weight of the body affected and the capacity for heat of the substance of which this body is composed. Thus a pound of water and a pound of lead at the same temperature contain very different quantities of heat, since the capacity of the lead for heat is only 0.0314 times that of water.

Intensity of heat, or temperature, is entirely independent of quantity, since we may have a small quantity of heat of high intensity, such as the heat in a needle raised to incandescence, or a large quantity of heat of low intensity, such as the heat in a large steel bar at a temperature of, say, 100° Fahrenheit.

All bodies, no matter what their temperature, within the range of temperatures so far obtained, possess a certain quantity of heat, but no body can impart any of the heat that it possesses to another body unless the intensity of this heat is higher than that of the heat in the body to which it is to be imparted, and this is entirely independent of the relative quantities of heat possessed by the two bodies. Thus a cubic foot of water at a temperature of 60° will possess a greater quantity of heat than a cubic foot of lead at a temperature of 100°, but if they are brought together the lead will impart heat to the water and not the water to the lead.

The amount of heat that can be transferred between different bodies depends upon the quantity of heat possessed by the hotter bodies, and not merely upon the difference in temperature. Thus a pound of water at a temperature of 70° Fahrenheit can impart more heat to a pound of water at a temperature of 60° Fahrenheit, than can a pound of iron at a temperature of 100° Fahrenheit. From these examples it can be seen that quantity of heat does not depend solely upon intensity, though, of course, for any definite weight of a given substance the quantity of heat possessed will vary directly as the intensity of the heat.

311. What is the effect of heat upon the volume of any given weight or quantity of gas, and what bearing has this effect upon the question of the measurement of gas?

Ans. The volume of a given weight of gas, that is, the space occupied by the quantity of gas possessing this weight, is increased when the temperature of the gas increases, and is decreased when the temperature decreases. It has been found by careful and accurate measurement that the exact amount of this increase or decrease is $\frac{1}{273}$ part of the volume of the gas at 0° C. for each change of 1° C. in the temperature. This is equivalent to an increase of $\frac{1}{273 \times 1.8} = \frac{1}{491.4}$ (or as it is usually taken $\frac{1}{492}$) part of the volume at 32° F. for each change of 1° F. in the temperature of the gas. The rule is sometimes given approximately as being, that the volume increases 1% of the original volume for each increase of 5° F.

in the temperature, the original volume being measured at the temperature, whatever it may be, that it may happen to possess. But for accurate work it is necessary to remember that the increase in volume for an increase in temperature of 1° F. is not the $\frac{1}{491.4}$ part of the volume at any temperature, but only that part of the volume at 32° F. It must also be borne in mind that this rule applies only to dry gas, that is, gas perfectly free from moisture.

Since according to the above law the same weight or quantity of gas possesses very different volumes at different temperatures, it follows that in order to obtain proper comparisons between amounts of gas measured under different conditions of temperature, it is necessary to know the temperature at which the gas is measured in each case. Thus if the temperature of the gas as it passes through the station meter of a gas works varies considerably, either with the seasons or from any other cause, the working results will apparently be poorer when the temperature at the meter is low than they will when this temperature is high, though actually the reverse might be the case. Therefore, in order to obtain accurate figures for comparison it is necessary that the average temperature of the gas at the station meter be determined from the temperatures obtained by frequent observation, and that the volume of the gas as measured at these temperatures be reduced to the corresponding volume at a standard temperature, which is usually taken as 60°, and the working results calculated from this corrected volume. This correction of volume for temperature is also necessary if accurate information is to be obtained as to the actual amount of gas lost by leakage in the distributing system, since if the temperature at the station meter is high and that at the consumers' meters low and no correction is made, the amount of gas unaccounted for will be much higher than the actual loss by leakage.

312. Give the formula by which the volume, measured at any pressure and temperature, of a gas saturated with moisture can be corrected to the standard conditions of 60° F. and

a pressure of 30 in. of mercury, and explain the manner in which the formula is derived.

Ans. The formula by which the volume, measured at any pressure and temperature, of a gas saturated with moisture can be corrected to the standard conditions of a temperature of 60° F. and a pressure of 30 in. of mercury is $V = \frac{17.64\,(h-a)v}{(460 + t)}$ in which V = the corrected volume at 60° and 30 in., v = the volume observed at a temperature of $t°$ and a pressure of h in. of mercury, and a = the tension of aqueous vapor at a temperature of $t°$.

This formula may be expressed in words as follows: The corrected volume of a gas saturated with water vapor under the standard conditions of 60° F. and 30 in. barometric pressure is equal to the observed volume multiplied by 17.64 times the difference between the observed barometric pressure and the tension of water vapor at the observed temperature, and divided by the sum of 460 and the observed temperature in Fahrenheit degrees. The tension of water vapor for the observed temperature must be found from the table giving the tensions for the different temperatures.

The formula is derived in the following manner:

Representing the volume at 60° F. and 30 in. pressure by V and that of the same mass of gas at any other temperature t and any other pressure h, by v, we can from the laws governing the change of volume of gases under the influence of changes in temperature and pressure derive the required formula for dry gases. Since the volume varies inversely as the pressure, the product obtained by multiplying the volume at any pressure by that pressure is equal to the product obtained by multiplying the volume of the same mass of gas at any other pressure by the corresponding pressure and we have,

$$30\,V = h\,v \text{ or } V = \frac{h}{30}\,v.$$

Gases expand or contract $\frac{1}{492}$ part of their volume at 32° F. for each change in temperature of 1° F., hence the effect of temperature is shown by the equation $V\,(460 + t) = 520\,v$, since t is the number of degrees above 0, and therefore 460 + t is equal to 492, the number of parts at 32° F., plus one volume for each degree increase in temperature above 32° F., while 520 is the number of parts to which 492 parts at 32° will have expanded when the temperature is raised to 60°. From this we obtain the equation, $V = \frac{520v}{460 + t}$. Combining these two equations we have for dry gases $V = \frac{v \times h \times 520}{30\,(460 + t)}$, that is, the volume corrected to the standard conditions of 60° F. and a pressure of 30 in. of mercury is equal to the observed volume multiplied by the observed pressure in inches of mercury multiplied by 520 and divided by 30 times the sum of 460 and the observed temperature.

The correction for moisture depends on the fact that a gas saturated with water vapor, as will be a gas in contact with and over water, will under the same conditions of temperature and pressure always contain the same quantity of water vapor. This vapor exerts a certain pressure which increases with the temperature, and is proportional to the amount of vapor present. The pressure so exerted has been determined in inches of mercury for each degree of temperature. To correct for the presence of moisture in a gas saturated with water vapor it is necessary to deduct the pressure due to the tension of this vapor from the observed barometric pressure, since this barometric pressure is resisted partly by the pressure of the water vapor and partly by that of the gas, and therefore the pressure exerted on the gas will be really only the difference between the barometric pressure and the pressure due to the tension of the water vapor. Calling this tension of water vapor a, and taking its value at the temperature of 60° (0.518) to deduct from the standard barometric pressure of 30 in., we have for the formula for reducing the volume of gas saturated with water vapor observed at any temperature and pressure to that of gas saturated with water vapor at 60° and 30 in.,

$$V = \frac{(h-a) \times 520 \times v}{(30 - 0.518) \times (460 + t)} = \frac{(h-a) \times 520 \times v}{29.482\,(460 + t)}$$

or, dividing both numerator and denominator of the fraction by 29.482, $V = \frac{17.64\ (h-a)\ v}{460 + t}$

313. A station meter passed a volume of gas at a temperature of 72° F. and registered 1,000 cubic feet; what would the same gas measure if its temperature were reduced to the standard of 60° F.? Give your calculations.

Ans. Applying the formula derived in the answer to question No. 312 to the present example in which the observed volume $v = 1{,}000$ cubic feet, the observed temperature $t = 72°$, the observed pressure, which is not given, is assumed to be 30 in., thus making the correction one for temperature only and the tension of water vapor at 72°, a, is 0.785, V (corrected volume at 60°) =

$$\frac{(30 - 0.785) \times 17.64 \times 1000}{460 + 72} = \frac{29.215 \times 17.64 \times 1000}{532} = \frac{515353}{532} = 968.7 \text{ cubic feet.}$$

The values of the fraction $\frac{17.64\ (h - a)}{460 + t}$ have been calculated for each $\frac{1}{10}$ in. of pressure from 28 in. to 31 in., and for each 2° of temperature from 40° to 84°, and the table so formed is given in Newbigging's "Gas Engineers' Hand Book" and Hornby's "Gas Engineers' Laboratory Hand Book." From this table the number by which it is necessary to multiply the volume observed at any pressure and temperature in order to obtain the correct volume at 60° and 30 in. can be found. The numbers for the odd numbered degrees can be obtained by interpolation.

314. Why does the ignition of a mixture of gas and air in the proper proportions produce an explosion?

Ans. When a mixture of air and gas in the proper proportions is ignited, the combustion that ensues spreads through the mixture at a very rapid rate. This rapid combustion brings about, by the heat developed, a very rapid rise in temperature and consequently a great expansion of the gases resulting from the combustion, and it is this expansion that produces the effects that are denoted by the term explosion. If the ignition and combustion were to occur where no resistance was offered to the expansion there would be no increase in pressure, but when they occur in a more or less confined space the expansion produces a sudden increase in pressure to which is due the damage done. Even when the ignition of an explosive mixture occurs in the open air the pressure of the atmosphere will, where a large quantity of the mixture is present, offer sufficient resistance to the rapid expansion of the gases to cause an explosion.

A mixture of air and illuminating gas is explosive only when the proportions of air and gas are such that the combustion, when started at any one point, will spread rapidly throughout the whole space filled by the mixture. If either too little or too much gas is present, the flame will not spread because the excess of air or of gas keeps the temperature below the ignition point unless heat is supplied from an outside source. To be explosive the mixture must not contain less than 8 per cent. nor more than 19 per cent. of gas, or, using a different form of expression, it must not contain more than 11½ parts of air to one of gas, nor less than 4 parts of air to one of gas. Mixtures either richer or poorer in gas will not explode, the gas simply burning at any point that is heated to the temperature of ignition without any spread of the flame from this point.

315. What is meant by the calorific value of a substance? How is the calorific value of a substance determined?

Ans. By the calorific value of a fuel is meant the total number of heat units that are developed by the complete oxidation of all the combustible materials contained in unit weight or unit volume of the fuel.

In the case of gases the calorific value is ordinarily expressed in heat units per cubic foot. Thus hydrogen has a calorific value of 328 B. t. u. (British thermal units) per cubic foot. In other words, the heat developed by the complete oxidation or burning of one cubic foot of hydrogen to water is equal to that necessary to raise 328 lb. of water 1° F. from its temperature of greatest density, 39.1° F.

In the case of liquids and solids the calorific value is expressed in heat units per pound. Thus carbon has a calorific value of 14,647 B. t. u. per pound when burned completely to carbon dioxide gas, CO_2.

The complete combustion of hydrogen, or of substances which contain hydrogen, produces water, which, while it is liquid at ordinary atmospheric temperatures, is a vapor at the temperatures at which the products of combustion often escape under the conditions of the combustion of gases. To convert a pound of water from the liquid state to that of vapor at 212° F. 966 heat units are required. When the calorific value of a substance is determined by means of a calorimeter the water vapor is condensed and its latent heat is set free and is included in the calorific value, as is also the heat given out by the condensed water in cooling from a temperature of 212° F. to that at which it leaves the calorimeter. Each pound of hydrogen burns to 9 lb. of water, so for each pound of hydrogen in the combustible there will be a difference between the true calorific value and the amount of heat available when the products of combustion escape at a temperature of 212° F. of $9 \times 966 = 8694$ B. t. u., plus the number of British thermal units given out by 9 lb. of water in cooling from a temperature of 212° F. to that at which the products of combustion leave the calorimeter. If the temperature of the products of combustion is reduced to 60° F. by the calorimeter, the amount of heat given off by the water produced from 1 lb. of hydrogen will be approximately $(212 - 60) \times 9 = 152 \times 9 = 1{,}368$ B. t. u., and the difference between the total calorific value of 1 lb. of hydrogen and the heat available when the water remains as vapor will be $8{,}694 + 1{,}368 = 10{,}062$ B. t. u. If, therefore, the total calorific value of hydrogen, as determined by the calorimeter, is 62,100 B. t. u., the heat available when the water escapes in the form of vapor at 212° F., will be $62{,}100 - 10{,}062 = 52{,}038$ B. t. u., and the heat available per cubic foot will be 275 B. t. u. In the same way, knowing the percentage of hydrogen contained in any substance, the heat available with the water as vapor can be obtained by making the proper deduction from the total value.

The calorific value of an elementary substance such as carbon or hydrogen can be obtained only by experiment. In making such determinations, an instrument called a calorimeter is used. This is so arranged that the heat produced by the combustion of a known weight, or volume, of the substance is imparted without any loss to a known weight of water. By observing the temperature of the water both before and after the combustion has taken place, the extent to which the water has been heated is determined and the heat absorbed by the water, which is necessarily that produced by the combustion, can then be easily calculated. The instrument must be so designed and handled that no loss of heat takes place, or at least so that any heat that is not accounted for is an inappreciable percentage of the total.

In the case of a compound substance the calorific value can either be obtained by experiment or, with more or less accuracy, by calculation. When the substance is a gas and an accurate analysis is available the calorific value can be obtained very accurately from the calorific values of its combustible constituents and the percentage in which each is present. When the substance is in the solid or the liquid state any determination of the calorific value made by calculation is approximate only, since so far it has been found impossible to determine exactly the effect produced upon the calorific value of a gas by the entrance of this gas into a compound which exists as a solid, or a liquid. For instance, hydrogen as it exists in coal has not the same calorific value as it possesses when it exists as a gas, and although various formulas have been worked out for the calculation of the calorific values of different kinds of coal from their chemical composition, these formulas, while they may fit the particular samples of coal used in the experiments from which they are worked out, do not give accurate results when applied to other samples. It is therefore more accurate to determine the calorific value of compound substances in a solid state or a liquid state by calorimeter tests than by calculation. This is also true of gaseous substances when, as is usual in the case of illuminating gas, the exact composition is not shown by the analysis, there being grouped together in one item several substances giving similar chemical reactions but possessing widely differing calorific values.

316. Give the calorific value, in British thermal units, of a pound, and in the case of gases also that of a cubic foot, of each of the following substances :

Carbon, C	Methane or Marsh Gas, CH_4
Carbon Monoxide, CO	Ethylene or Olefiant Gas, C_2H_4
Hydrogen, H_2	Ethane, C_2H_6
Benzene, C_6H_6	Acetylene, C_2H_2

Ans.	Per Pound.	Per Cu. Ft.
Carbon, C	14,647	
Carbon Monoxide, CO	4,383	325
Hydrogen, H_2	62,100	328
Benzene, C_6H_6	18,094	3,732
Methane or Marsh Gas, CH_4	24,017	1,016
Ethylene or Olefiant Gas, C_2H_4	21,898	1,621
Ethane, C_2H_6	22,338	1,772
Acetylene, C_2H_2	21,856	1,502

The figures given by different experimenters for the calorific value of gases vary, as do the figures for the weights of a cubic foot of the gases, and, therefore, the figures for the calorific value per cubic foot also vary. Thus Newbigging, quoting from Letheby, gives the following figures for the calorific value per cubic foot :

H_2	329
CH_4	996
CO	320
C_2H_2	1,251
C_6H_6	3,860

and the Committee on Education of the American Gas Light Association, quoting from Julius Thomsen, gave for some of the same gases :

H_2	325.5
CH_4	1,022.8
CO	334.7
C_2H_2	1,493.4

The values first given above are based on the determinations of calorific value made by Berthelot as given in Poole's "Calorific Power of Fuels," and the weight of gases calculated from the weight of air as determined by Regnault and afterwards corrected for slight errors.

These figures give in each case the total calorific value. The amounts of heat available with water as vapor, figured as explained in the answer to question No. 315, are given below. In figuring on problems in combustion, in which fuels containing hydrogen are used under conditions such that the water remains in the state of vapor these values should always be employed to arrive at the true results.

	Per Pound.	Per Cu. Ft.
Hydrogen, H_2	52,038	275
Benzene, C_6H_6	17,322	3.572
Methane or Marsh Gas, CH_4	21,502	910
Ethylene or Olefiant Gas, C_2H_4	20,461	1,515
Ethane, C_2H_6	20,336	1,613
Acetylene, C_2H_2	21,081	1,448

317. An illuminating gas has the following composition by volume:

Carbon Dioxide, CO_2	1.40%
Oxygen, O_2	0.49%
Illuminants	4.85%
Carbon Monoxide, CO	7.25%
Hydrogen, H_2	48.15%
Marsh Gas, CH_4	35.72%
Nitrogen, N_2	2.14%

Calculate the calorific value per cubic foot, assuming the illuminants to be made up of 80% of ethylene, C_2H_4, and its homologues, and 20% of benzene, C_6H_6.

Ans. To calculate the calorific value per cubic foot of an illuminating gas the composition, by volume, of which is known, it is necessary to multiply the calorific value per cubic foot of each combustible constituent of the gas by the volume of such constituent contained in a cubic foot, as shown by the analysis, and then add together the products of these multiplications, the sum so obtained being the required calorific value per cubic foot of the gas.

The combustible constituents of the gas, the analysis of which is given in the question, are the Illuminants, Carbon Monoxide, Hydrogen and Marsh Gas. Analyses of illuminating gas as commonly made do not afford exact information as to the composition of the hydrocarbons which, as is done in this case, are often grouped together under the name of Illuminants or Heavy Hydrocarbons. Since the calorific values of the various hydrocarbons which may be present in such a group are widely different, this uncertainty as to which ones are present and in what proportion, makes the calculated calorific value of the gas subject to considerable error, and these calculated values can only be accepted as being accurate when the analysis has been very carefully made and includes a comparatively close subdivision of the heavy hydrocarbons. No such subdivision having been made in the question, it is necessary to assume one and the assumption may, or may not, be correct.

From the answer to question No. 316 the calorific values are obtained as follows, in British thermal units per cubic foot.

Ethylene	1621
Benzene	3732
Carbon Monoxide	325
Hydrogen	328
Marsh Gas	1016

Since the illuminants are assumed to be 80% ethylene and 20% benzene the percentages of each assumed to be contained in the gas is 4.85 × 0.80 = 3.88% of ethylene and 4.85 × 0.20 = 0.97% of benzene.

100 cu. ft. of the illuminating gas under consideration therefore contains, according to the assumption stated,

3.88	cu. ft. of	Ethylene
0.97	"	Benzene
7.25	"	Carbon Monoxide
48.15	"	Hydrogen
35.72	"	Marsh Gas

and the calorific value derived from the quantity of each of the components contained in 100 cu. ft. will be

Ethylene	3.88	×	1621	=	6289	B. t. u.
Benzene	0.97	×	3732	=	3620	"
Carbon Monoxide	7.25	×	325	=	2356	"
Hydrogen	48.15	×	328	=	15793	"
Marsh Gas	35.72	×	1016	=	36292	"
Total					64350	"

The calorific value per cubic foot of the gas is therefore 643.5 B. t. u.

In round numbers 15% of the calorific value is derived from the illuminants, 4% from the carbon monoxide, 25% from the hydrogen and 56% from the marsh gas.

318. An illuminating gas has the following composition by volume:

Carbon Dioxide..........	CO_2	2.7	per cent.
Oxygen..................	O_2	0.7	"
Heavy Hydrocarbons.....	C_nH_{2n}	12.8	"
Carbon Monoxide.........	CO	30.7	"
Hydrogen	H_2	32.4	"
Marsh Gas...............	CH_4	13.9	"
Higher Paraffins..........	C_nH_{2n+2}	2.4	"
Benzene Vapor...........	C_6H_6	0.6	"
Nitrogen.................	N_2	3.8	"

Calculate the calorific value per cubic foot, assuming the heavy hydrocarbons to be Olefiant Gas, C_2H_4, and the higher paraffins to be Ethane, C_2H_6. Calculate also the amount of heat available when the water produced by combustion remains as vapor as explained in the answer to question No. 315.

Ans. The calorific value per cubic foot of an illuminating gas can be calculated, when the composition by volume of the gas is known, by multiplying the calorific value per cubic foot of each combustible constituent of the gas by the volume of such constituent contained in a cubic foot, as shown by the analysis, and then adding together the products of these multiplications, the sum obtained by this addition being the required calorific value per cubic foot of the gas.

The combustible constituents of the gas, the analysis of which is given in the question, are the Heavy Hydrocarbons which are to be considered as being Olefiant Gas, C_2H_4, Carbon Monoxide, CO, Hydrogen, H, Marsh Gas, CH_4, the Higher Paraffins which are to be considered as being Ethane, C_2H_6, and the Benzene Vapor.

The values per cubic foot for these various gases are as follows:

	Calorific value.	Heat available with water as vapor.
Heavy Hydrocarbons taken as....C_2H_4	1,621	1,515
Carbon Monoxide................CO	325	325
Hydrogen........................H_2	328	275
Marsh Gas........................CH_4	1,016	910
Higher Paraffins taken as........C_2H_6	1,772	1,613
Benzene Vapor..................C_6H_6	3,732	3,572

Therefore, the calorific value of the gas is $(1621 \times 0.128) + (325 \times 0.307) + (328 \times 0.324) + (1016 \times 0.139) + (1772 \times 0.024) + (3732 \times 0.006) = 207.5 + 99.8 + 106.3 + 141.2 + 42.5 + 22.4 = 619.7$ heat units, and the heat available with water as vapor is $(1515 \times 0.128) + (325 \times 0.307) + (257 \times 0.324) + (910 \times 0.139) + (1613 \times 0.024) + (3572 \times 0.006) = 193.9 + 99.8 + 89.1 + 126.5 + 38.7 + 21.4 = 569.4$ heat units.

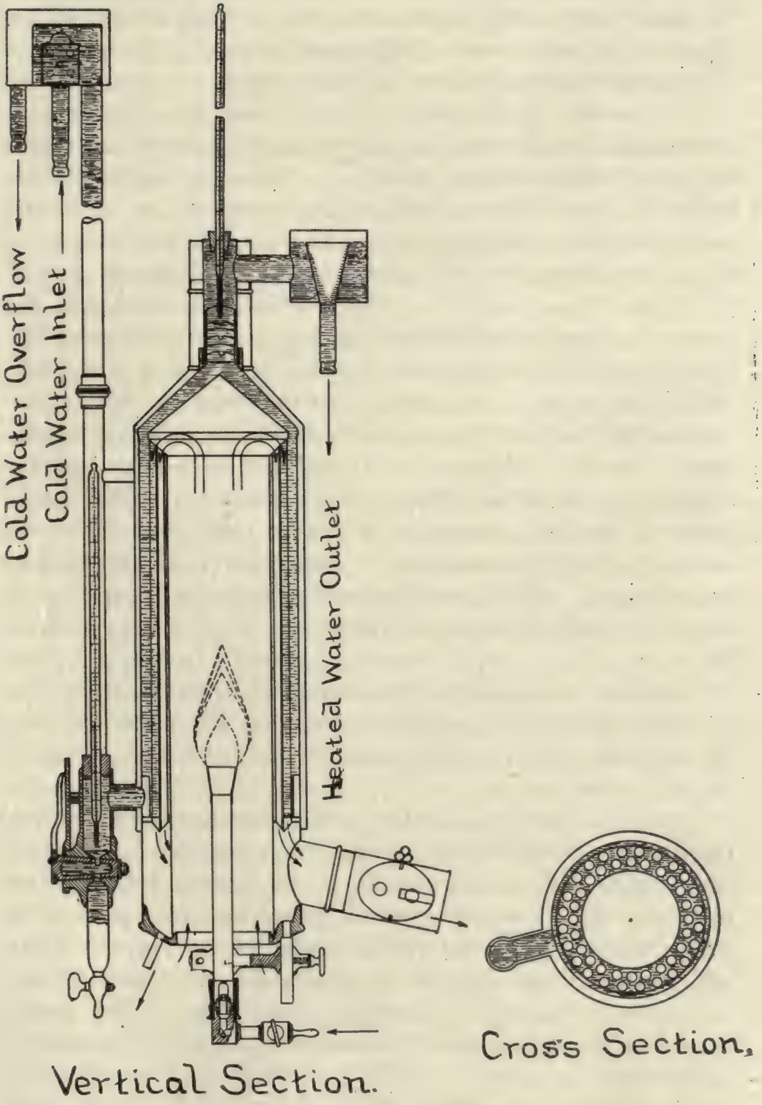
As stated in the answer to question No. 317 the exact composition of the hydrocarbons grouped in the analysis under the respective designations of "Heavy Hydrocarbons" and "Higher Paraffins" is not certain. It is probable that the calorific values assumed for these groups are lower than the actual values and that therefore the calculated calorific value of the gas is lower than the value that would be shown by a calorimetric test. Many gas analysts and physicists use a calorific value of 2,000 B. t u. per cubic foot for both these groups. Whatever values are assumed the calculated calorific value of a gas as complex as is illuminating gas is always of doubtful accuracy as compared with an actual determination by means of a calorimeter.

Under the assumptions made, 44% of the calorific value of the gas is derived from the heavy hydrocarbons, higher paraffins and benzene combined, or, in other words, from the total illuminants, 16% from the carbon monoxide, 17% from the hydrogen and 23% from the marsh gas. Of the heat available with the water in a state of vapor 45% is derived from the illuminants, 18% from the carbon monoxide, 15% from the hydrogen and 22% from the marsh gas.

319. Describe some form of calorimeter by the use of which the calorific value of gas can be determined by observation.

Ans. The calorimeter that is most commonly used in this country for determining, by observation, the calorific value of gases, is an improved form of the Hartley Calorimeter, designed by Hugo Junkers and known as the Junkers Calorimeter. It acts by transferring the heat developed by the combustion of a measured quantity of gas to a measured quantity of water which flows at a constant rate through the apparatus.

The calorimeter itself is an annular vessel made of two concentric copper cylinders, the outer cylinder having a diameter of about seven inches and the inner one a diameter of about four inches. To the top of the outer cylinder is fitted a conical hood which closes the whole top of the vessel, except for a circular opening left at the apex of the cone. A smaller hood which begins as a frustrum of a cone with its base upwards and then changes to a cone with its apex upwards, is attached to the inner cylinder so that the annular space is continued up between the two hoods and the space within the inner cylinder is shut off at the top from this annular space. The bottom of the inner cylinder is left open and the bottom of the annular space is closed by a ring. At a distance of four or five inches above this ring is fastened another ring forming a water-tight partition which divides the annular space into two compartments. Through the upper one of these two compartments pass a number of small copper tubes,



JUNKERS CALORIMETER.

the upper ends of which are fastened to the diverging cone of the inner hood while the lower ends are fastened to the partition described above. The joints between the tubes and the hood and partition must be water-tight.

Into one side of the outer cylinder, just above the bottom of the upper compartment, opens a copper pipe set at a right angle to the axis of the cylinders. This pipe enters the side outlet of a tee piece set with its run vertical and about two inches from the cylinder. From the lower outlet of the tee the pipe is dropped a short distance and then passing around a U-shaped turn rises to a height of about 20 in. above the top of the annular vessel and ends in a small cistern or cup formed inside of a larger one, both cups having a common bottom supported by the pipe. To the part of this bottom covered by the small cup is attached a corrugated nipple, over which a rubber tube can be slipped, and a similar nipple is fastened in the space outside of the small cup. The upper outlet of the tee is closed by a rubber cork pierced for the insertion of a thermometer. A stop cock provided with an arrow-shaped handle, moving over a graduated quadrant, is placed between the tee and the bend. Opposite the opening of the pipe in the outer cylinder is placed a baffle plate forming a small annular space extending completely around the cylinder, the object of which is to cause the water entering through the pipe to be uniformly distributed all around the annular chamber.

To the circular opening left, as described above, at the apex of the outer hood is fitted a copper tube provided with several baffle rings with centre openings. This tube ends in a tee piece, the upper end of which is closed by a cork pierced for a thermometer, and from the side outlet of this tee runs a pipe which ends in and supports by its side a cup. Inside the cup is a funnel ending in a nipple for tubing, which passes through and is fastened with a water-tight joint to the bottom of the cup.

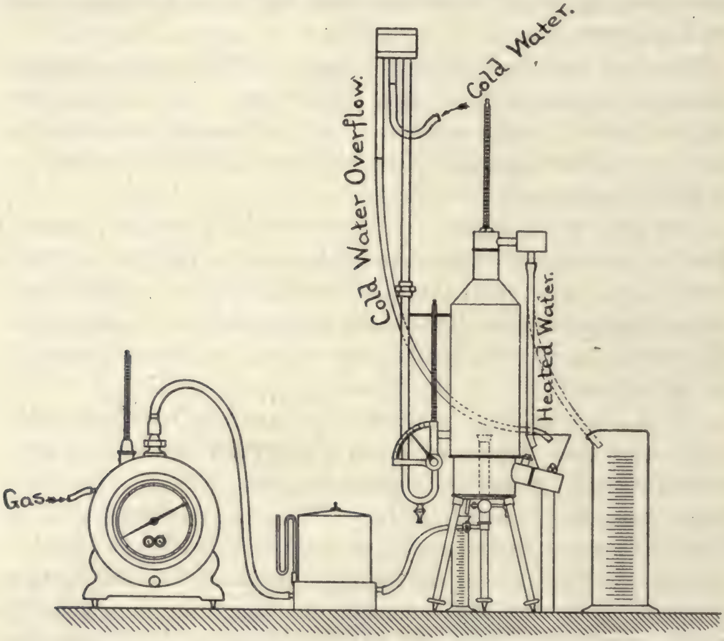
On one side of the lower compartment of the annular space is an elliptical opening leading into a tube of the same cross section. Provision is made for the insertion of a thermometer into this tube as close as possible to the outer cylinder, and it is also fitted with an ordinary stove pipe damper. At a point diametrically opposite to this tube a small tube is tapped into the bottom ring, and directly under it is tapped in a rod which serves to support the burner through which the gas is consumed.

To prevent loss of heat by radiation the whole of the body of the calorimeter above a point an inch or two below the bottom of the upper compartment is jacketed by a highly polished nickel-plated copper cylinder made sufficiently large to leave an annular air space one-half inch wide between it and the calorimeter.

When set up, the apparatus stands on three removable legs provided with levelling screws. Reference to the accompanying sections of the calorimeter will, in connection with the above description, enable the construction of the apparatus to be fully understood.

Two measuring glasses are provided with the calorimeter. The larger one will hold two litres and is graduated in intervals of five cubic centimetres. The other is an ordinary 100 cubic centimetre glass, graduated to one-half of a centimetre. (A litre is 1,000 cubic centimetres and a litre of water weighs one kilogram.)

When it is desired to make a determination of the calorific value of a gas, the apparatus is set up on a firm base in such a position that it can be readily supplied with the gas to be tested and with flowing water. The thermometers provided for the purpose, which are graduated in tenths of degrees Centigrade from 0° to 50°, should be inserted in the proper openings, as described above. Connection is then made to the water supply by means of rubber tubing slipped over the nipple on the bottom of the smaller inside cup, of the two supported by the pipe which enters the calorimeter at the bottom of the upper compartment. A rubber tube leading to a drain is slipped over the nipple opening from the larger cup in the space outside the small one, and another tube is slipped on the nipple leading from the funnel in the cup supported by the pipe coming out of the tube at the top of the conical hood. Water being turned on flows into the small cup and thence down through the pipe around the U bend, up through the stop cock, around the bulb of the thermometer inserted into the tee and into the annular space around the tubes. It rises through this space and passes up the central tube, in which it is thoroughly mixed by the baffle rings, over the bulb of the thermometer inserted into the tee at the top of the tube and thence by the side pipe to the cup in which it rises until it overflows into the funnel and passes away by a rubber tube slipped over the funnel nipple. By admitting water into the small cup at a faster rate than that at which it is admitted to the calorimeter, this cup is filled and water overflows from it into the larger cup from which it runs off through the nipple and tube to the drain. In this way a constant head for the supply of water is maintained, and as the water also overflows into the funnel on the outlet at a constant height, the effective head is constant and the water must flow through at a constant speed as long as the stop cock remains set at any given opening.



JUNKERS CALORIMETER AND AUXILIARY APPARATUS SET UP READY FOR USE.

The gas to be consumed is led to the apparatus through an experimental meter, by which it is measured, and a sensitive governor, by which the pressure, and consequently the rate of flow for any given opening of the stop cock, is kept constant. For illuminating gas a bunsen burner is used and the gas is burned at the rate of five to six cubic feet per hour. After being lighted the burner is placed inside the inner cylinder and clamped to the rod provided for this purpose. The clamp arm is of such a length and the rod is so flattened that when the set screw is tightened the axis of the burner coincides with the axis of the calorimeter, and it is fastened at a height that brings the bottom of the flame five to six inches above the lower edge of the apparatus.

The products of combustion rise inside the inner cylinder until they strike the inner hood and then pass down through the tubes to the lower annular compartment and out through the outlet flue to the air. In the passage up the inside of the cylinder and through the tubes they impart their heat to the water surrounding the tubes and emerge from the apparatus at a temperature either exactly or very nearly that of the entering water, which should be the same as that of the air. Any water vapor formed by the combustion of the gas is condensed and runs off through the small pipe tapped into the ring closing the bottom of the lower annular compartment.

To make a test, water is started flowing through the apparatus, and the gas burner lighted and put in place and the flow of gas adjusted to the proper rate. The flow of water is then adjusted by the graduated stop cock to a rate that will give the desired difference in temperature between the outgoing and incoming water. This difference is usually kept between 10° and 20° C. When the temperature of the outgoing water, as shown by the thermometer at the top of the calorimeter, is at the desired point and remains constant, and the condensed water has begun to drop from the tube at the bottom, a test can be made. The hand of the meter must be watched, and as it passes the zero mark the end of the tube through which the heated water is flowing must be inserted in the large graduated measure and the small measure placed under the condensed water outlet. Four or five observations of the temperature of the water as it enters and leaves the apparatus must be made and recorded at regular intervals. When the meter hand crosses the zero mark after making either one or two revolutions, depending upon the rate at which the water is flowing, the hot water tube must be removed from the measure and the water allowed to run to waste again. The observed temperatures are then averaged and the difference between the outlet and inlet temperatures obtained. The amount of water collected in the measuring glass is read off in cubic centimetres by means of the scale marked on the glass, and this amount reduced to litres and decimals of a litre by dividing by 1,000 or pointing off three decimal places. Since a Calorie is the quantity of heat required to raise the temperature of one kilogram of water 1° C. and a litre of water weighs one kilogram, the product obtained by multiplying the amount of water collected, measured in litres, by the number of Centigrade degrees by which its temperature is raised, is the number of Calories absorbed by the water and consequently the number produced by the combustion of the measured quantity of gas. This number can be changed to British thermal units by multiplying it by 3.968, one Calorie being equal to that number of British thermal units, and from this figure and the quantity of gas used the calorific value of the gas in British thermal units per cubic foot can be readily found.

The result so obtained is the calorific value of the gas, the water formed having been condensed in the calorimeter, and it is to enable the amount of heat available with the water in the state of vapor to be determined that this condensed water is collected and measured. The amount can be measured for each test, but since the quantity is comparatively so small that the unavoidable error in reading amounts to a large percentage, it is best to allow one cubic foot of gas to be burned and use the amount of condensed water collected during the combustion of this quantity of gas as an average to be employed for each of the different tests made at that particular time. Having the amount of condensed water, the latent heat of the steam corresponding to it can be calculated and deducted from the calorific value to obtain for the gas under test the amount of heat available with the water in the state of vapor. A convenient rule is that for every cubic centimetre of water so condensed per cubic foot of gas burned, a deduction of 0.6 Calorie, or 2.382 British thermal units must be made from the calorific value per cubic foot to obtain the amount of heat available with the water in the state of vapor.

The above description of the instrument, and of its use in making a test, is based upon the form in which the Junkers Calorimeter has usually been sold and used in the United States. However, since the calorific value of a gas is expressed in this country in terms of British thermal units per cubic foot it is desirable that the instrument should be so equipped as to enable the result of a test to be calculated directly in such terms. For this purpose the meter should be made to pass 0.1 cubic foot per revolution of the drum, the thermometers should be graduated in Fahrenheit degrees and show accurately 0.1°, and the water heated during the test should be weighed on scales graduated to 0.01 lb. instead of being measured according to the metric system.

When it is necessary that the results obtained should be exact, the temperature of the gas, and those of the inlet water, the escaping products of combustion and the air of the room should all be the same. For ordinary commercial work it is sufficient that these temperatures should be within say five degrees.

The subject of calorimeters and their use for determining the calorific value of gas is exhaustively treated in the report of a Committee on Calorimetry made to the American Gas Institute at the meeting in 1908 and published in Vol. III of the Proceedings, page 285.

320. A calorimeter test made on a certain illuminating gas gave the following data: Gas consumed, 0.1 cubic foot; average temperature of water entering the calorimeter, 16.67° C.; average temperature of water leaving the calorimeter, 25.23° C.; average temperature of escaping products of combustion, 17.05° C.; quantity of water collected, 1992 cubic centimetres; quantity of condensed water collected, 27 c. c. per cubic foot of gas consumed; temperature of gas at meter,

63° F.; height of barometer, 29.33 in. Calculate both the calorific value of the gas and the amount of heat available with the water in a state of vapor at a temperature of 212° F.

Ans. Since, as stated in the answer to question No. 319, a litre (1000 c. c.) of water weighs 1 kilogram, and the amount of heat required to raise the temperature of 1 kilogram of water 1° centigrade is a Calorie, the product obtained by multiplying the amount of water collected, measured in litres, by the number of centigrade degrees by which its temperature is raised, is the number of Calories absorbed by the water and, consequently, the number produced by the combustion of the measured quantity of gas.

In the particular experiment noted the water enters at a temperature of 16.67° C. and leaves at one of 25.23° C. The temperature is therefore raised 8.56° C. The volume of water collected is 1992 c. c. or 1.992 litres. The heat produced by the combustion of 0.1 cubic foot of gas is therefore $8.56 \times 1.992 = 17.05$ Calories, and the calorific value per cubic foot measured at a temperature of 63° F. and a barometric pressure of 29.33 in. is 170.5 Calories. A Calorie equals 3.968 B. t. u., so the corresponding value is $170.5 \times 3.968 = 676.54$ B. t. u. But from the tables for the correction of the volume of gases we find that the quantity of gas that occupies a volume of 1 cubic foot at a temperature of 63° F. and a pressure of 29.33 in. will, under the standard conditions of a temperature of 60° F. and a pressure of 30 in., occupy a volume of 0.970 cubic feet. Consequently, the calorific value of a foot of the gas under test measured under the standard conditions, or as it is called the calorific value corrected for temperature and pressure will be $\frac{676.54}{0.97} = 697.5$ B. t. u.

The amount of heat available with the water in the state of vapor is obtained, as explained in the answer to question No. 319, by deducting from the calorific value 2.38 B. t. u. for each cubic centimetre of condensed water collected per cubic foot of gas burned. In the present case 27 c. c. of condensed water were collected, so the uncorrected value for available heat is equal to $676.54 - (27 \times 2.38) = 676.54 -$

64.26 = 612.28 B. t. u. To obtain the corresponding value corrected for temperature and pressure, this must be divided by 0.97 for the reasons given above, and this corrected value is 631.2 B. t. u.

321. A calorimeter test made on a certain illuminating gas gave the following data: Gas consumed, 0.2 cu. ft.; average temperature of water entering the calorimeter, 72.74° F.; average temperature of water leaving the calorimeter, 88.09° F.; average temperature of escaping products of combustion, 75.2° F.; weight of water heated, 7.57 lb.; temperature of gas at meter, 72.68° F.; temperature of room, 72.6° F.; height of barometer, 29.26 in. Calculate the calorific value of the gas.

Ans. Since a British thermal unit is the amount of heat required to raise the temperature of 1 lb. of water 1° F., the product obtained by multiplying the weight in pounds of the water heated by the number of degrees Fahrenheit by which its temperature is raised is the number of British thermal units absorbed by the water and consequently the number produced by the quantity of gas burned in the test.

As the water enters at a temperature of 72.74° F. and leaves at one of 88.09° F. its temperature is raised 15.35°. The weight of water collected is 7.57 lb. The heat produced by the combustion of the quantity of gas which under the given conditions of temperature and pressure measures 0.2 cubic foot is therefore $15.35 \times 7.57 = 116.2$ B. t. u., and the calorific value, per cubic foot measured under these conditions, is 581.0 B. t. u. But the tables for the correction of volume of gases show that the quantity of gas which occupies a volume of 1 cubic foot at a temperature of 72.68° F. and a pressure of 29.26 in. will, under the standard conditions of a temperature of 60° F. and a pressure of 30 in., occupy a volume of 0.942 cubic feet. Consequently, the calorific value of a cubic foot of the gas under test corrected for temperature and pressure will be $\frac{581}{0.942} = 616.8$ B. t. u.

322. A certain illuminating gas has a calorific value of 680

heat units per cubic foot. It is desired to bring to a temperature of 148° F. two gallons of water placed in a pot and over a burner which together will put into the water 29% of the calorific value of the gas. The water at the start has a temperature of 60° F. The barometer marks 30 in. atmospheric pressure. How much gas must be burned to produce the desired result?

Ans. As the gas has a calorific value of 680 heat units per cubic foot and the burner and pot enable 29% of the heat developed by the gas to be imparted to the water, each cubic foot of gas will give to the water $\frac{29}{100} \times 680 = 197.2$ heat units. To raise the temperature of one pound of pure water from 60° F. to 148° F., $148 - 60 = 88$ heat units will be required. The weight of a gallon of water at a temperature of 60° F. is commonly taken as 8.33 lb., and, therefore, two gallons will weigh 16.66 lb. To raise the temperature of this weight of water from 60° F. to 148° F. there will be required $88 \times 16.66 = 1{,}466$ heat units. Since each cubic foot of gas used supplies 197.2 heat units, there will be required to supply 1,466 heat units $\frac{1466}{197.2} = 7.4$ cubic feet. If all the heat the gas is capable of producing could be imparted to the water there would be required only 2.15 cubic feet. The difference between this amount and that actually required is due to the imperfections of the apparatus.

323. Has the method of burning a cubic foot of gas any effect on the quantity of heat produced, if the combustion is complete?

Ans. The method of burning a cubic foot of gas has no effect on the *quantity* of heat produced, if the combustion is complete. The *temperature of the flame* is affected by the conditions under which the gas is burned.

324. What relation, if any, is there between the calorific value of an illuminating gas and its illuminating value when consumed in a standard luminous flame burner?

Ans. There is no definite relation between the calorific value of an illuminating gas and its illuminating value when consumed in a luminous flame burner. The greater part of the calorific value is derived from components which do not of themselves furnish illuminating value, and by reason of change in composition it is possible for an illuminating gas to vary considerably in calorific value and yet be of the same illuminating value or to vary in illuminating power while remaining of practically the same heating value.

In the case of different samples of coal gas made from the same coal, but of different candle-powers by reason of being produced by carbonization of the coal at different temperatures, there is a fairly constant proportion between the illuminating value and the calorific value, as there is also, within certain limits of candle-power, in the case of different samples of carburetted water gas made from the same oil, but this relation does not hold between gases made from different coals or different kinds of oil.

In a lecture delivered before the Institute of Gas Engineers, Prof. V. B. Lewes gave the following table as the average relation between candle-power and calorific value as determined by a number of tests, but said that the results in any particular case might vary 5 per cent. either way from these, and even with this qualification exception was taken to the figures by some gas engineers. They stand, however, as the most definite statement yet published.

Candle power.	Calorific value B. t. u. per cubic foot. Coal gas.	Calorific value B. t. u. per cubic foot. Carburetted water gas.
12	540	490
13	560	510
14	585	529
15	610	547
16	625	567
17	647	587
18	670	607
19	690	627
20	712	647

325. What is the meaning of specific heat as used in the statement "the specific heat of nitrogen is 0.244?"

Ans. "Specific heat" as used in the statement quoted in the question denotes the amount of heat expressed in heat units which is required to raise by 1° the temperature of unit weight of a substance. Since a heat unit is the amount of heat required to raise by 1° the temperature of unit weight of water, the specific heat of a substance is the ratio between the amount of heat needed to raise by 1° the temperature of unit weight of the substance and the amount of heat required to raise by 1° the temperature of unit weight of water. If the unit of weight is the pound avoirdupois and the temperature is measured in Fahrenheit degrees the specific heat is expressed in British thermal units, while if the unit of weight is the kilogram and the temperature is measured in Centigrade degrees the specific heat is expressed in Calories. It is expressed by the same number in each case. More heat is required to raise the temperature of unit weight of water a given amount than is needed to raise by the same amount the temperature of unit weight of any other substance, with the exception of hydrogen; therefore, with this exception, the specific heats of all substances are less than 1.

The amount of heat required to raise by 1° the temperature of a body which is free to expand, or, as it is said, is kept under constant pressure, is not the same as the amount required to produce the same change in temperature in the body if it is kept at a constant volume. For every substance there are, therefore, two values for the specific heat, one for constant pressure and one for constant volume. There is also what is termed specific heat by volume, which is the amount of heat, expressed in heat units, required to raise by 1° the temperature of unit volume of a substance. But when the term specific heat is used without any qualification, as in the statement "the specific heat of nitrogen is 0.244" and in the first paragraph of this answer, it refers to specific heat by weight and at constant pressure.

326. Is the specific heat of a gas or vapor at *constant pressure*—that is, when free to expand, as gas in a holder, greater or less than the specific heat of the same gas or vapor at *constant volume*—that is, when confined, as steam in a boiler? Give the reasons for your answer.

Ans. The specific heat of a gas or vapor, when free to expand, is greater than the specific heat of the same gas or vapor when confined; that is, it requires more heat to raise the temperature of a given volume of gas or vapor from any point to a higher point when free to expand, than to raise the same volume through the same range of temperature, the gas or vapor being confined. The reason for this will be evident after a little thought. In raising the temperature of a confined gas or vapor, as steam in a boiler, it is only required to add the heat necessary to increase the temperature of the gas or vapor from the point at which it starts to the desired temperature. If, however, the gas or vapor is free to expand. it will expand as heated, and in expanding it must displace, or lift, the atmosphere pressing upon it an amount equivalent to the expansion. Thus, if the gas is in a holder having an area of 100 square feet, as its temperature increases the gas expands and the holder rises, say, one foot. Now, the holder has done mechanical work equivalent to lifting the entire weight of the atmosphere, bearing upon the holder (about 15 lb. for each square inch of the area of the holder), through one foot in height, and the heat necessary to the accomplishment of this work must be supplied to the gas, and is in addition to the heat necessary to raise the temperature of the gas if confined.

327. Give the specific heats, both for constant pressure and constant volume, of carbon monoxide, carbon dioxide, nitrogen, hydrogen, oxygen and water vapor.

Ans. The specific heats often used as those of the various substances named in the question are those determined by Regnault. These are given in a table in Hornby's Gas Engineers' Laboratory Handbook, page 294 (1894 edition), as follows:

	Constant pressure.	Constant volume.
Carbon Monoxide, CO	0.2479	0.1758
Carbon Dioxide, CO_2	0.2164	0.1535
Nitrogen, N_2	0.2440	0.1730
Hydrogen, H_2	3.4046	2.4146
Oxygen, O_2	0.2182	0.1548
Water Vapor	0.4750	0.3337

It has been found, however, that the specific heats of gases increase quite rapidly with increase in temperature, so that the use of constant values for the specific heats in problems involving widely differing temperatures does not give accurate results. In connection with a lecture delivered before the American Gas Light Association in 1903, Mr. Alfred H. White gave tables showing the specific heats of the various products of combustion for temperatures varying by 100° C. from 100° C. to 2500° C. Copies of these tables with the temperatures converted into degrees Fahrenheit are given below. Inaccuracies in the experimental data on which these tables are based render it useless to attempt to interpolate more closely than 90°.

TABLE OF MEAN SPECIFIC HEATS EXPRESSED IN B. T. U. PER POUND.

	CONSTANT PRESSURE				CONSTANT VOLUME			
Degrees Fahrenh't	Carbon Dioxide	Water Vapor	Nitrogen	Oxygen	Carbon Dioxide	Water Vapor	Nitrogen	Oxygen
212	0.201	0.446	0.244	0.214	0.156	0.337	0.174	0.152
392	0.210	0.462	0.249	0.218	0.165	0.353	0.179	0.156
572	0.219	0.478	0.253	0.222	0.174	0.369	0.183	0.160
752	0.227	0.494	0.257	0.225	0.183	0.385	0.187	0.164
932	0.236	0.510	0.262	0.229	0.192	0.401	0.192	0.168
1112	0.245	0.526	0.266	0.233	0.200	0.416	0.196	0.171
1292	0.254	0.541	0.270	0.237	0.209	0.432	0.200	0.175
1472	0.263	0.557	0.275	0.241	0.218	0.448	0.205	0.179
1652	0.271	0.573	0.279	0.244	0.227	0.464	0.209	0.183
1832	0.280	0.589	0.284	0.248	0.236	0.480	0.213	0.187
2012	0.289	0.605	0.288	0.252	0.244	0.496	0.218	0.190
2192	0.298	0.621	0.292	0.256	0.253	0.512	0.222	0.194
2372	0.307	0.637	0.297	0.260	0.262	0.528	0.226	0.198
2552	0.315	0.652	0.301	0.264	0.271	0.544	0.231	0.202
2732	0.324	0.668	0.305	0.267	0.280	0.560	0.235	0.206
2912	0.333	0.684	0.310	0.271	0.288	0.575	0.239	0.209
3092	0.342	0.700	0.314	0.275	0.297	0.591	0.244	0.213
3272	0.351	0.716	0.318	0.279	0.306	0.607	0.248	0.217
3452	0.360	0.732	0.323	0.282	0.315	0.623	0.253	0.221
3632	0.368	0.748	0.327	0.286	0.324	0.639	0.257	0.225
3812	0.377	0.764	0.331	0.290	0.332	0.655	0.261	0.229
3992	0.385	0.780	0.336	0.294	0.341	0.671	0.266	0.232
4172	0.394	0.796	0.340	0.298	0.350	0.687	0.270	0.236
4352	0.403	0.812	0.344	0.301	0.359	0.703	0.274	0.240
4532	0.412	0.828	0.349	0.305	0.368	0.719	0.279	0.244

In using these tables it is necessary to assume a temperature and then use in the calculation the specific heats corresponding to this assumed temperature. If the calculated temperature does not agree closely with the assumed one, it is necessary to assume another temperature and do the work over again, continuing this process until a close agreement is obtained between the assumed and the calculated temperatures.

328. What is meant by the theoretical flame temperature of a gas?

Ans. The theoretical flame temperature of a gas is the highest temperature that can be obtained by the combustion of the gas when no heat is lost in any way, all the heat that is developed being employed to heat up the products of combustion. These conditions are, of course, never obtained in practice, but, as it is difficult to measure accurately the losses that do occur, the theoretical flame temperatures are used to furnish a basis for comparisons between different gases, it being assumed that the relations between the temperatures actually obtained will be very nearly the same as those existing between the theoretical temperatures, although the absolute temperatures will be very different.

The theoretical temperature depends upon the relation between the quantity of heat developed by the combustion of a unit weight of the gas and the amount of heat required to raise, by one degree, the temperature of the products resulting from the combustion of this unit weight. This latter amount depends upon the weight of the products and their specific heat or capacity for heat. Therefore, a gas which yields a small weight of products of combustion with low specific heats, will produce a high flame temperature even though its heating value is comparatively low.

Hydrogen and hydrocarbon gases containing a large percentage of hydrogen, yield upon combustion large weights of aqueous vapor which has a high specific heat and, consequently, in spite of their high calorific value, do not produce as high flame temperatures as do such gases as carbon monoxide, which have a lower calorific value, but give smaller weights of products, having a lower specific heat than aqueous vapor.

Since when the gas is burned in air the weight of the nitrogen mixed with the oxygen in the air is added to that of the products of combustion, the flame temperature is lower when the combustion takes place in air than it is for combustion in oxygen, as is practically illustrated in the Oxy-hydrogen flame.

329. How would you calculate the maximum temperature that can be produced by burning any given sample of gas, the oxygen for combustion being derived from the atmosphere?

Ans. The highest temperature that can theoretically be obtained by burning a gas in air is the temperature that will be reached when no heat is lost in any way, all the heat developed being employed to heat up the products of combustion and the nitrogen accompanying the oxygen drawn from the air for this combustion. These conditions are of course never obtained in practice, but, as it is very hard to measure accurately the losses that occur in practice, the maximum theoretical temperatures are used to furnish a basis for comparisons between different gases, it being assumed that the relations between the temperatures actually obtained will be very nearly the same as those existing between the theoretical temperatures, although the absolute temperatures will be very different in the two cases.

This maximum theoretical temperature evidently depends upon the quantity of heat developed by the combustion of a unit weight of the gas and upon the quantity of heat required to raise, by one degree, the temperature of the products resulting from the combustion of this unit weight, and the quotient obtained by dividing the quantity of heat produced by the quantity required to raise the temperature of the products of combustion one degree will give the greatest increase in temperature that can be reached by burning the given gas. The quantity of heat produced is given by the calorific value of the gas. The amount of heat required to raise the temperature of the products of combustion one degree can be calculated by multiplying the weight of each product that is produced by its specific heat, the nitrogen mixed with the oxygen in the air and drawn into the flame with it being included. It is therefore necessary to determine what substances are produced by the combustion of the gas and the weight of each of these substances that is obtained from a unit weight of the gas, to multiply the determined weight of each substance by its specific heat and to add together the numbers obtained by these multiplications, the sum forming the divisor of the fraction.

The maximum temperature that can be produced by burning a gas in air can therefore be determined by dividing the calorific value of the gas, per pound, by the sum of the numbers obtained by multiplying the weight of each of the products of combustion produced from 1 lb. of gas by its proper specific heat, the nitrogen mixed in the air with the oxygen required for combustion being considered as one of the products of the combustion, and adding to the figure so obtained the initial temperature of the gas and air, which, unless stated, may be taken as 60° F.

The values at ordinary temperatures of the specific heats at constant pressure of the products of combustion are often used in determining the maximum flame temperatures that can be obtained, but this is not correct, because the specific heats of gases increase with the temperature and therefore the use of the specific heats at ordinary temperatures makes the calculated temperatures too high. The specific heats of the ordinary products of combustion are given, for a wide range of temperatures, in the table which forms part of the answer to question No. 327.

To illustrate by a simple example, the maximum temperature that can be produced by the combustion of carbon monoxide, CO, may be determined as follows:

1 lb. of CO requires for its combustion to carbon dioxide, CO_2, 0.571 lb. of oxygen, which will have mixed with it in the air $0.571 \times 3.31 = 1.89$ lb. of nitrogen, N_2, and the products of the combustion of 1 lb. of CO will therefore be 1.571 lb. of CO_2 and 1.89 of N_2. The calorific value of CO is 4383 B. t. u. per pound. Assuming a flame temperature of 3632° the specific heats of CO_2 and N_2 are respectively 0.368 and 0.327 and the equation for the maximum increase in temperature in degrees Fahrenheit is

$$T = \frac{4383}{1.571 \times 0.368 + 1.89 \times 0.327} = \frac{4383}{1.196} = 3665° \text{ F.}$$

Adding 60° to this the flame temperature would be 3725°. The difference between the assumed and the calculated temperature is too great, so it is necessary to make another calculation.

Assuming 3812° as the temperature, the specific heats of CO_2 and N_2 are found to be 0.377 and 0.331 respectively and the maximum increase in temperature is

$$T = \frac{4383}{1.571 \times 0.377 + 1.89 \times 0.331} = \frac{4383}{1.218} = 3599^\circ \text{ F.}$$

Adding 60° to this the flame temperature would be 3659°, and again the difference between the assumed and the calculated temperatures is too great. But in this case the assumed temperature is larger than the calculated, while in the first calculation the reverse was true, therefore it is necessary to interpolate between these two assumed temperatures because the table does not give intermediate temperatures.

Taking the temperature midway between the two already used, which is 90° greater than the first temperature assumed and 90° less than the second, and is as close as the table can be used, the specific heats of CO_2 and N_2 at 3722° are respectively 0.3725 and 0.329, and the maximum increase in temperature in degrees Fahrenheit is

$$T = \frac{4383}{1.571 \times 0.3725 + 1.89 \times 0.329} = \frac{4383}{1.207} = 3631^\circ \text{ F.}$$

Adding 60° to this the flame temperature would be 3691°. This is as near to the assumed temperature as it is possible to figure from the table and can therefore be taken as the theoretical flame temperature of carbon monoxide gas.

330. Calculate the theoretical flame temperature that can be produced when hydrogen, H_2, marsh gas, CH_4, and olefiant gas, C_2H_4, are being burnt in air.

Ans. According to the answer to question No. 329 the maximum increase in temperature that can be produced by burning a gas in air can be determined by dividing the calorific value of the gas, per pound, by the sum of the numbers obtained by multiplying the weight of each of the products of combustion from 1 lb. of gas by its proper specific heat, the nitrogen mixed in the air with the oxygen required for combustion being considered as one of the products of the combustion. For gases containing hydrogen the heat available with the water in the state of vapor must be taken, since it is evident that the water produced by the combustion of the hydrogen will pass off as vapor.

Applying the rule previously given to the different gases named in the question, the following results are obtained: The heat available from 1 lb. of hydrogen with the water in the state of vapor is 52,038 B. t. u.; and the products of its combustion are 9 lb. of aqueous vapor and 26.48 lb. of nitrogen, as given in the answer to question No. 290. Assuming a flame temperature of 3452° F. it is found from the table given in answer to question No. 327 that the mean specific heat of water vapor for this temperature is 0.732 and that of nitrogen is 0.323. This gives for the fraction from which to determine the increase in temperature

$$\frac{52038}{9 \times 0.732 + 26.48 \times 0.323} = \frac{52038}{6.588 + 8.553} = 3437^\circ.$$

Adding to this 60°, which is the normal temperature of the atmosphere, will give a flame temperature of 3497°. The maximum flame temperature that can be produced by the combustion of hydrogen and air may therefore be taken as being in round numbers 3500° F.

The heat available from 1 lb. of marsh gas with the water in the state of vapor is 21,502 B. t. u.; and the products of its combustion are 2.25 lb. of aqueous vapor, 2.75 lb. of carbon dioxide and 13.24 lb. of nitrogen. Assuming a flame temperature of 3092° F. the table gives the mean specific heats for this temperature as carbon dioxide 0.342, water vapor 0.700 and nitrogen 0.314. The fraction from which to determine the increase in temperature is therefore $\frac{21502}{2.75 \times 0.342 + 2.25 \times 0.7 + 13.24 \times 0.314} =$ $\frac{21502}{0.840 + 1.575 + 4.1574} = \frac{21502}{6.5724} = 3272^\circ$ F. Adding 60° in this case will give a flame temperature of 3332°, but the difference between the assumed and calculated temperatures is too great, so it is necessary to assume another temperature. Taking this as 3272° the mean specific heats are carbon dioxide 0.351, water vapor 0.716 and nitrogen 0.318. The fraction for the increase in temperature thus becomes

$$\frac{21502}{2.75 \times 0.351 + 2.25 \times 0.716 + 13.24 \times 0.318} =$$

$$\frac{21502}{0.965 + 1.611 + 4.21} = \frac{21502}{6.786} = 3169°.$$ Adding 60°, gives a flame temperature of 3229° F. This is only 43° lower than the assumed temperature, which is within the limits of error for the table of specific heats.

The heat available from 1 lb. of olefiant gas with the water in the state of vapor is 20,461 B. t. u.; and the products of its combustion are 1.29 lb. of aqueous vapor, 3.14 lb. of carbon dioxide and 11.35 lb. of nitrogen.

Assuming a temperature of 3542° F. and interpolating for the mean specific heats, these are found to be, carbon dioxide 0.364, water vapor 0.74 and nitrogen 0.325. The calculated increase in temperature is therefore to be found from the fraction

$$\frac{20461}{3.14 \times 0.364 + 1.29 \times 0.74 + 11.35 \times 0.32} =$$

$$\frac{20461}{1.143 + 0.955 + 3.689} = \frac{20461}{5.787} = 3535°.$$ Then 3535° + 60° = 3595° F., which is near enough to the assumed temperature to be allowed to stand.

The flame temperatures of any other gases can be found in the same manner.

331. Calculate the theoretical flame temperature of an illuminating gas which has the following composition by volume:

Carbon Dioxide	CO_2	2.7%
Oxygen	O_2	0.7%
Heavy Hydrocarbons		12.8%
Carbon Monoxide	CO	30.7%
Hydrogen	H_2	32.4%
Marsh Gas	CH_4	13.9%
Higher Paraffins	C_nH_{2n+2}	2.4%
Benzene Vapor	C_6H_6	0.6%
Nitrogen	N_2	3.8%

It is assumed that combustion takes place in air and that the heavy hydrocarbons are Olefiant Gas, C_2H_4, and the higher paraffins are Ethane, C_2H_6. (See answers to questions No. 318, No. 290 and No. 327.)

Ans. The maximum temperature that can be produced by burning the gas in air can be determined by adding to the original temperature of air and gas, which may be taken as 60° as no other figure is stated, the quotient obtained by dividing the calorific value of the gas per pound by the sum of the numbers obtained by multiplying the weight of each of the products of combustion produced from 1 pound of gas by its proper specific heat, the nitrogen mixed in the air with the oxygen required for combustion being considered as one of these products.

The heat available per cubic foot of the gas in question, with the water in the state of vapor has already been given in the answer to question No. 318 as 569.4 B. t. u.

The amount of heat required to raise the temperature of the products of the combustion of the gas 1° F. is found by obtaining the sum of the numbers given by multiplying the weight of each of the different products of combustion by its proper specific heat. The weights of the products of combustion can be obtained from the answer to question No. 290 by multiplying the weights of the products per pound of combustible as given there by the weight of that volume of each substance which is shown by the analysis of the gas to enter into combustion. For the sake of avoiding an excessive number of decimal places in each multiplication, the calculation will be made on the basis of the combustion of 1,000 cubic feet of the gas.

In each 1,000 cubic feet of the gas there will be,

27	cubic feet	of	Carbon Dioxide,
7	"	"	Oxygen,
128	"	"	Olefiant Gas,
307	"	"	Carbon Monoxide,
324	"	"	Hydrogen,
139	"	"	Marsh Gas,
24	"	"	Ethane,
6	"	"	Benzene Vapor,
38	"	"	Nitrogen.

The weight of each constituent per 1,000 cubic feet of the gas will therefore be (see answer to question No. 294):

Carbon Dioxide,	27 × 0.11634 = 3.141	lb.
Oxygen,	7 × 0.08462 = 0.592	"
Olefiant Gas,	128 × 0.07404 = 9.477	"
Carbon Monoxide,	307 × 0.07404 = 22.730	"
Hydrogen,	324 × 0.00529 = 1.714	"
Marsh Gas,	139 × 0.04231 = 5.881	"
Ethane,	24 × 0.07933 = 1.904	"
Benzene Vapor,	6 × 0.20625 = 1.238	"
Nitrogen,	38 × 0.07404 = 2.814	"

The weights of the products of combustion of each constituent will be:

Constituents.	Products.	
	CO_2	H_2O
Carbon Dioxide,	3.141	
Olefiant Gas,	3.14 × 9.477 = 29.758	1.29 × 9.477 = 12.225
Carbon Monoxide,	1.57 × 22.730 = 35.686	
Hydrogen,		9.00 × 1.714 = 15.426
Marsh Gas,	2.75 × 5.881 = 16.173	2.25 × 5.881 = 13.232
Ethane,	2.94 × 1.904 = 5.598	1.80 × 1.904 = 3.427
Benzene Vapor,	3.39 × 1.238 = 4.197	0.69 × 1.238 = 0.854
Nitrogen,		
	94.553	45.164

	N_2
Olefiant Gas,	11.35 × 9.477 = 107.564
Carbon Monoxide,	1.89 × 22.730 = 42.960
Hydrogen,	26.48 × 1.714 = 45.387
Marsh Gas,	13.24 × 5.881 = 77.864
Ethane,	12.38 × 1.904 = 23.572
Benzene Vapor,	10.19 × 1.238 = 12.615
Nitrogen,	2.814
	312.776

Since the oxygen in the gas originally would aid in the combustion, there would be required so much less from the air, and therefore the weight of nitrogen would be reduced by the nitrogen associated in the air with 0.592 lb. of oxygen, or 0.592 × 3.31 = 1.96 lb., and the total products of combustion would be 94.553 lb. of carbon dioxide, 45.164 lb. of water vapor and 312.776—1.96 = 310.816 lb. of nitrogen.

The values at ordinary temperatures of the specific heats at constant pressure of the products of combustion are often used in determining the maximum flame temperatures that can be obtained, but this is not correct, because the specific heats of gases increase with the temperature. Therefore the use of the specific heats at ordinary temperatures makes the calculated temperatures too high, and the specific heats to be used in working out the problem should be taken from the table given in the answer to question No. 327.

Assuming a flame temperature of 3632° the specific heats as given in the table will be,

Carbon Dioxide	0.368
Water Vapor	0.748
Nitrogen	0.327

and the theoretical rise in temperature produced by the combustion will equal,

$$\frac{569400}{94.553 \times 0.368 + 45.164 \times 0.748 + 310.816 \times 0.327} =$$

$$\frac{569400}{34.80 + 33.78 + 101.64} = \frac{569400}{170.22} = 3345° \text{ F.}$$

Adding 60° to this the flame temperature would be 3405°. The difference between the assumed and the calculated temperature is too great, so it is necessary to make another calculation.

Assuming 3452° as the temperature the specific heats are found to be,

Carbon Dioxide	0.360
Water Vapor	0.732
Nitrogen	0.323

and the theoretical rise in temperature produced by the combustion will equal,

$$\frac{569400}{94.553 \times 0.360 + 45.164 \times 0.732 + 310.816 \times 0.323} =$$

$$\frac{569400}{34.04 + 33.06 + 100.39} = \frac{569400}{167.49} = 3399° \text{ F.}$$

Adding 60° to this the flame temperature would be 3459°. This is practically the same as that assumed and can therefore be taken as the theoretical flame temperature of the gas named in the question.

This temperature can never be attained under actual conditions, since it is impossible to prevent losses of heat that result in keeping the temperature of the flame from reaching the theoretical height.

332. What is meant by "The Mechanical Equivalent of Heat," and what is its value expressed in foot pounds per heat unit (British thermal unit)?

Ans. The "Mechanical Equivalent of Heat" is the amount of mechanical energy which is equivalent to (that is, which when transferred into heat will produce) one heat unit. (Century Dictionary.)

The first accurate determination of the value of this constant quantity was made in 1849 by Joule, who measured the amount of heat produced by the friction of a paddle wheel in a vessel of water, the energy required to turn the paddle being derived from the descent of a known weight through a known distance. He found that to raise the temperature of one pound of water 1° F. required the expenditure of 772 foot pounds of mechanical work, viz: the force resulting from the fall of one pound of matter through the space of 772 feet, or of 772 pounds of matter through one foot of space. Later investigations seem to indicate that a higher value (about 778 foot pounds) is more accurate, but nearly all the tables and all work done up to date are based upon the value of 772 foot pounds for the mechanical equivalent of one British thermal unit.

333. What is a vapor? What is the difference between a true gas and a vapor?

Ans. Vapor, in physics, is the gaseous form which a solid or a liquid substance assumes when sufficiently heated. (Century Dictionary.)

As usually employed, vapor denotes the gaseous form of a substance which under ordinary conditions of pressure and temperature exists in a solid or liquid form. Thus, in common language, a difference is recognized between vapors and so-called true gases, since the latter are substances which exist normally in a gaseous state and can only be liquefied by being subjected to great pressure or intense cold, or both.

There is, however, no real physical difference between these two classes of gaseous forms, as it has been found possible to liquefy all gases and thus bring them before liquefaction into a condition exactly the same as that of vapors at ordinary temperatures and pressures.

What is called a vapor is a substance in gaseous form near the point of saturation, that is, near the point at which any further increase of pressure or decrease of temperature will cause a portion of the substance to condense into the liquid or the solid state, while what is called a true gas is a substance in gaseous form, far removed from its point of saturation, and therefore capable of being compressed and cooled without the occurrence of any condensation.

The difference between a "vapor" and a "true gas" is thus merely comparative, being the same that exists to a lesser degree between saturated steam and superheated steam, and strictly speaking no known substance can be termed a true gas, since none with which we are acquainted is sufficiently removed from the point of saturation to obey perfectly the laws of expansion and contraction under changes of pressure and temperature that would apply to absolutely perfect gases according to the molecular theory of matter, though the gases which are farthest removed from the point of saturation, and therefore the hardest to liquefy, such as hydrogen, conform very closely to these laws.

334. Give the temperature at which water boils when under pressures, as shown by a steam gauge, of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 pounds per square inch respectively.

Ans. The temperature at which water boils under various pressures is as follows:

10 lb. gauge pressure = 24.7 lb. absolute pressure 239°.38 F.
20 " " = 34.7 " " 258°.71 F.
30 " " = 44.7 " " 273°.93 F.
40 " " = 54.7 " " 286°.61 F.
50 " " = 64.7 " " 297°.52 F.
60 " " = 74.7 " " 307°.17 F.
70 " " = 84.7 " " 315°.83 F.
80 " " = 94.7 " " 323°.71 F.
90 " " = 104.7 " " 330°.96 F.
100 " " = 114.7 " " 337°.68 F.

335. What is saturated steam? What is superheated steam?

Ans. Saturated steam may be defined as steam formed directly from, and in contact with, water at the same temperature as the steam, and also as steam just at the point of condensation. Its condition is such that even though perfectly "dry," that is, not containing any water in mechanical suspension (entrained water) as long as its temperature and pressure remain unchanged, yet the slightest fall in temperature or increase in pressure will cause the condensation into water of a portion of the steam. Thus if a certain volume of saturated steam is made to assume a smaller volume, the temperature being kept constant, the pressure will remain the same, enough steam condensing into water to compensate for the reduction in volume of the space occupied. Saturated steam therefore differs from a permanent gas in that it cannot be compressed under constant temperature without changing its physical state; that is, without a portion of it condensing to a liquid.

Superheated steam is "steam which for the same pressure has a greater temperature" and "for any particular weight a greater volume than saturated steam at the same pressure." It is produced by heating saturated steam out of contact with water and thus, if the pressure is kept constant, causing it to expand as its temperature increases. Steam in this condition resembles to a certain extent a permanent gas. If compressed under constant temperature the pressure will at first increase inversely as the volume. However, as the compression continues the steam finally reaches the point of saturation and thereafter the pressure cannot be increased by further compression under constant temperature.

It is advantageous to use superheated steam in steam engines, but it is difficult to attain to any considerable degree of superheating either in a boiler or in a separate superheater, since it is almost impossible to prevent the burning out of the material subjected to the high temperature of the flue gases on one side, and that of the superheated steam on the other. As a rule horizontal boilers produce saturated steam, while vertical boilers produce steam slightly superheated.

336. What is the meaning of the term "latent heat of a vapor," and what is the value of this "latent heat" in the case of steam?

Ans. "Latent heat of a vapor is the quantity of heat which must be communicated to a liquid in order to convert it into a vapor without change of temperature." (*Maxwell.*)

When heat is supplied in sufficient quantity to a substance its temperature is increased up to a certain point at which, provided the pressure is kept constant, it will remain stationary, no matter how much heat is applied, until the substance has completely changed its physical state; that is, if originally solid has become liquid, or if liquid has become a vapor. There is thus a certain amount of heat required to produce a change of physical state which does not produce any effect upon the temperature of the body undergoing the change. When heat was believed to be a material substance and therefore indestructible, the only way in which this apparent disappearance of heat could be explained was by assuming that the quantity not accounted for by change in temperature was hidden away or "latent" in the body ready to be given out again when the converse change of state took place. But under the kinetic theory of heat it is known that heat being merely one form of actual or kinetic energy can be converted into other forms of energy and cease to be heat, and that in the phenomenon of change of physical state that portion of the heat form of energy not employed in increasing the energy of vibration of the molecules (that is, in increasing the temperature and producing heat) is employed in doing two classes of work, 1st, that of overcoming the pressure of the substance enveloping the body undergoing the change of state as it expands through a space represented by the difference in volume between the two states, and 2d, that of overcoming the mutual attraction of the molecules for each other, and separating and rearranging them. In doing this work the heat form of kinetic energy is changed into energy of position or potential energy, the molecules of the body by virtue of the change in their position, due to the work expended on them, possessing the power of giving out energy or doing work by rushing together again when the converse change of state takes place, just as a heavy body raised to a high point possesses the power of doing work by falling to a lower point. Therefore the heat not employed in raising the temperature of the body ceases to exist as heat and the term "latent" is inaccurate and misleading. But it was too firmly fixed in the vocabulary of physics under the old theory to be gotten rid of, and if the definition given above be understood as the proper one, no error can arise from the use of the term. The amount of this latent heat varies with each vapor, and also varies for the same vapor as the pressure and, therefore, the temperature of the vapor is varied. For water vapor or steam the latent heat at atmospheric pressure is 966.069 British thermal units and at a gauge pressure of 100 lb. per square inch it is 876.511 British thermal units, with intermediate values for each intermediate pressure.

337. How much heat is required to change a pound of water at a temperature of 100° F. into steam at a gauge pressure of 70 lb.?

Ans. The amount of heat required to change a pound of water at a temperature of 100° F. into steam at a gauge pressure of 70 lb. is equal to the total amount of heat in a pound of steam at 70 lb. pressure less the amount of heat in a pound of water at a temperature of 100° F. The total amount of heat required to raise the temperature of a pound of water from 32° to that of the boiling point at any pressure and then convert it into saturated steam can be determined from the formula $H = 1081.4 + 0.305t$, in which H is the number of B. t. u. (British thermal units) required and t is the common temperature of the water and steam in degrees Fahrenheit. The temperature corresponding to any given pressure can be calculated from the formula $t = \frac{2938.16}{6.1993544 - \log p} - 371.85$, in which p is the absolute pressure in pounds per square inch and t is the temperature in degrees Fahrenheit.

In the problem set in the question the gauge pressure at which the steam is formed being 70 lb. the absolute pressure is 84.7 lb. and $t = \dfrac{2938.16}{6.1993544 - \log 84.7} - 371.85 = \dfrac{2938.16}{6.1993544 - 1.9278834} - 371.85 = \dfrac{2938.16}{4.271471} - 371.85 =$ $687.85 - 371.85 = 316°$ F. Substituting this value in the formula for the total heat we have $H = 1081.4 + 0.305 \times 316 = 1081.4 + 96.38 = 1177.78$ B. t. u.

The amount of heat required to raise the temperature of a pound of water from 32° F. to 100° F. can, unless extreme accuracy is necessary, be taken as being equal to 68 B. t. u., that is, one B. t. u. for each degree difference in temperature.

The heat required to convert a pound of water at a temperature of 100° F. into steam at a gauge pressure of 70 lb. will therefore be $1177.78 - 68 = 1109.78$ B. t. u.

Tables have been made out giving the quantity of heat in a pound of steam for absolute pressures from 0.5 lb. to 400 lb. per square inch, and are published in almost every book treating of the properties of steam. If copies of these tables are available the value of H need not be calculated but can be obtained from them in the following manner. As the pressure in the present problem is 84.7 the corresponding value for H will be less than that for 85 lb. by an amount equal to the product obtained by multiplying the difference between the values for 84 lb. and 85 lb. respectively by 0.3. The value for 84 lb. absolute pressure is given as 1177.6 and that for 85 lb. as 1177.9 B. t. u. The difference between them is 0.3 B. t. u. Hence the value for 84.7 lb. equals $1177.9 - (0.3 \times 0.3) = 1177.9 - 0.09 = 1177.81$. Subtracting 68 from this as before gives the heat required to convert a pound of water at a temperature of 100° F. into steam at a gauge pressure of 70 lb., which will therefore be $1177.81 - 68 = 1109.81$ B. t. u. The difference between the result as calculated and that obtained from tables is due to the difference in the number of decimal places employed in the two cases.

338. What is meant by the tension of a vapor? By maximum vapor tension?

Ans. By the tension of a vapor is meant the pressure exerted by the vapor against the walls of a vessel containing it or in opposition to any other restraining force. The pressure is due to the force with which the molecules of the vapor, as they move more or less freely along straight lines, strike against the walls of the vessel or move in a direction opposite to that of the force.

The tension of a vapor is also the measure of the extent to which it can resist compression, and the maximum vapor tension, sometimes called simply the vapor tension of a substance, is the heaviest pressure which it can resist, when in contact with some of the liquid from which it is produced, that is, when saturated, without a portion of the vapor being condensed back to the liquid form. For any given vapor this maximum tension varies with the temperature, being greater as the temperature is higher.

At the same temperature each vapor has its own maximum tension, the vapors of liquids boiling at low temperatures having greater tensions than those of liquids boiling at high temperatures. High "vapor tensions" therefore correspond to low boiling points, and, conversely, low "vapor tensions" to high boiling points.

339. What is meant by the statement that a gas is saturated with vapor at a certain temperature and pressure?

Ans. A gas is said to be saturated with vapor at a certain temperature and pressure when it contains the full amount of vapor that it can carry under these conditions. When a gas is so saturated it cannot be made to take up any more vapor unless its temperature is increased or its pressure reduced, and any increase of pressure or decrease of temperature will cause the condensation into the liquid state of a portion of the vapor. At any given temperature and pressure a definite quantity of any given vapor is required to saturate a gas, and this quantity is always the same for the same conditions.

340. What effect does the saturation of a gas with one vapor have upon the amount of other vapors that can be carried by the gas?

Ans. The effect produced by the saturation of a gas with one vapor upon its power of carrying other vapors depends upon the tension of the vapors in question, and upon the mutual solubility of the liquids from which the vapors are derived. Regnault's experiments prove that "when two liquids exert no solvent action on each other, the tension of the vapors which rise from them is nearly equal to the sum of the tensions of the two separate vapors at the same temperature; while with two liquids that partially dissolve each other, the tension of the mixture is much less than the sum of the tensions, being scarcely equal to that of the vapor with the higher tension; and with liquids that dissolve in all proportions the tension of the mixture is intermediate between the tensions of the separate vapors." From these laws it is seen that a gas may be saturated with a vapor without any interference with its capacity for carrying the vapors of liquids which are not soluble in each other, or in the liquid from which the first vapor is produced, since, as these vapors are added to the gas, the tension increases by the amount required to keep them from condensing. If, however, the vapors are from liquids which are soluble in each other, saturation of the gas by any one vapor reduces the capacity for vapors with higher tensions, since the increase in tension due to the addition of the new vapor is not sufficient to make the combined tension as high as would be the tension of the second vapor, if it existed in the gas alone. On the other hand, saturation with a vapor increases the capacity of the gas for vapors of lower tensions as long as the liquids from which the vapors are produced are soluble in each other, since the mean tension of the mixture of the vapors will be higher than that of the vapor of lowest tension, and, therefore, more of this vapor can be carried by the gas. Conversely, the addition of a vapor of very high tension to a gas already saturated with a mixture of vapors of low tension, all the vapors being those of liquids mutually soluble in each other, will slightly increase the capacity of the gas for carrying the low tension vapors, while the addition of a vapor of low tension to a gas saturated with vapors of higher tensions, will decrease the carrying capacity for these higher tension vapors.

341. What is the meaning of the term horse-power as

applied to steam engines? What is indicated horse-power? What is effective horse-power?

Ans. Horse-power, as applied to steam engines, is the unit of power by which is measured the quantity of work done, or of energy transformed, in the unit of time. In other words, it is a measure of the rate at which work is performed. Its value in British units is

550 foot-pounds per second, or
33,000 ‘‘ ‘‘ minute, or
1,980,000 ‘‘ ‘‘ hour.

Indicated horse-power is the work, expressed in horse-power, performed per minute by the steam upon the piston of an engine and is calculated from the mean effective pressure per square inch of piston shown by an indicator diagram, or diagrams, taken while the engine is at work. It is therefore the work done by the steam in the cylinder of a steam engine.

Effective horse-power is the work transmitted to the main shaft of an engine and thus made available for performing useful work. It is usually measured by means of a brake, and is therefore often called ''brake horse-power.'' It is of course always less than the indicated horse-power by the amount of the losses, chiefly frictional, in the engine.

342. How would you determine the horse-power that was being developed in the cylinder of a steam engine?

Ans. The horse-power developed by a steam engine is expressed by the quotient obtained by dividing the number of foot pounds of work developed by the engine in any interval of time by the number of foot pounds equivalent to one horse-power for the given time. The work developed by the engine is equal to the total pressure in pounds exerted by the steam on the piston, multiplied by the distance in feet over which it is exerted in the given interval, and can be found, taking the time as one minute, by obtaining the continued product of the mean effective pressure in pounds per square inch of the steam in the cylinder, the length of the stroke in feet, the net area of the piston in square inches and the number of strokes per minute. The product is then divided by 33,000. The rule may be expressed in the following formula: H. P. = $\frac{2 PLAN}{33,000}$ in which

P = Mean effective pressure of the steam in pounds per square inch.

L = Length of stroke in feet.

A = Net area of piston in square inches.

N = Number of revolutions per minute.

The mean effective pressure may be determined exactly by the use of an indicator, which is an instrument used to measure and register continuously and simultaneously the conditions of pressure and volume of the working fluid existing in the cylinder of a heat engine at work.

The indicator consists of a cylinder containing a piston working against a spring. Attached to the piston is a rod with its head so connected to a lever that the motion of the piston is multiplied and transferred to a pencil holder, the path of which is kept parallel to that of the piston by means of some form of parallel motion. A pencil placed in this holder can be brought into contact with a sheet of paper wrapped around a drum made to turn about its axis with a reciprocating motion by a cord wound around its base and connected to the proper point on a "pantagraph," or other form of "reducing motion," attached to and moving with the crosshead of the engine; which cord works in opposition to a spring fastened to the drum.

From the indicator cards obtained from both ends of the cylinder the mean effective pressure is found by determining the area enclosed by the diagram in each case. Dividing this area by its length the mean height is obtained, and this multiplied by the scale corresponding to the spring employed gives the mean effective pressure in pounds per square inch.

In the absence of any indicator cards from which to determine exactly the mean effective pressure of the steam it will be necessary to calculate this approximately from the boiler pressure and the point of cut-off, making a proper allowance for the back pressure. If the point of cut-off is not known it can be determined quite closely by opening the drip cocks on the cylinder, cracking the throttle valve and turning the engine slowly backwards by hand. The point of the stroke at which steam is first admitted to the cylinder when the engine is thus moved backwards will be shown by the steam beginning to escape from the drip cock, and this point, which can be obtained quite exactly by two or three trials, is obviously that at which the admission of steam is cut off when the engine is running. Knowing the point of cut-off and the initial pressure, which, if the steam pipes are covered and properly designed as to size, may be taken as from five to ten pounds less than the boiler pressure, according to the distance of the engine from the boiler, the mean pressure on the steam side of the piston can be obtained from steam engine tables. If the exhaust pipe is large and without sharp turns the back pressure should not exceed from three to five pounds, so the mean effective pressure will be obtained by deducting, say, five pounds from the mean steam pressure.

Knowing the initial pressure of the steam in the cylinder and the point of cut-off, an ideal indicator card may also be constructed from which the mean effective pressure can be calculated.

The number of revolutions made per minute can be obtained by a count when the engine is working under its load. All the factors being then known, the horse-power developed can be calculated in the manner explained above.

It must be understood that the horse-power thus calculated gives approximately the horse-power developed in the cylinder, namely, the indicated horse-power of the engine. The actual work which the engine is capable of doing is called the actual or brake horse-power, and is less than the indicated horse-power, the difference being the power required to overcome the friction-losses in the engine. The friction of the moving parts of the engine is too uncertain for estimate when the size of engine is unknown.

As an example, assume an engine with a stroke of 12 in. and a net piston area of 100 sq. in. making 100 revolutions per minute with a steam pressure by gauge of 100 lb. at the boiler. With a loss of 5 lb. between boiler and cylinder the initial cylinder pressure will be, say, 95 lb. The point of cut-off is determined to be at one-quarter stroke. Then from the tables we find that the mean absolute pressure of steam expanding according to Mariotte's law to a volume four times its original volume is equal to the initial absolute pressure multiplied by 0.597. Absolute pressures are pressures measured from a perfect vacuum and are equal to gauge pressures plus the pressure of the atmosphere, which is commonly assumed as equal to 14.7 lb. The initial absolute pressure in the assumed case is therefore $95 + 14.7 = 109.7$ lb., and the mean absolute pressure is $109.7 \times 0.597 = 65.5$, so the mean pressure as measured by a gauge would be $65.5 - 14.7 = 50.8$ lb. From this must be deducted the back pressure, assumed to be 5 lb., leaving the mean effective pressure 45.8 lb. The factors then are:

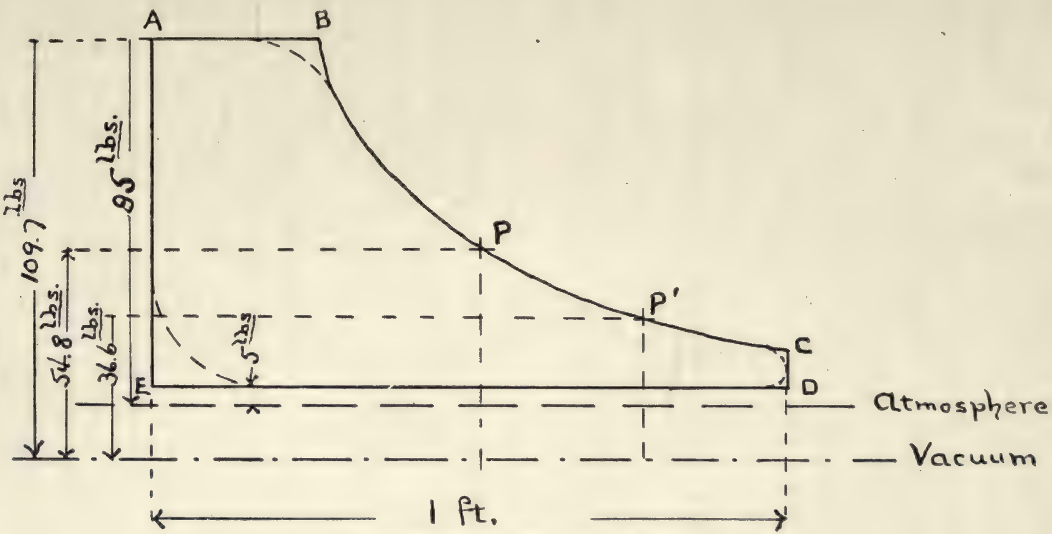
$P = 45.8$, $L = 1$, $A = 100$, $N = 100$ and the approximate indicated horse-power is:

$$\text{H. P.} = \frac{2 \times 45.8 \times 1 \times 100 \times 100}{33000} = \frac{91.6 \times 10000}{33000} = \frac{916000}{33000} = 27.7.$$

If it is desired to use a theoretical indicator card to calculate the mean effective pressure, such a card can be constructed from the above data in the following manner:

Lay off on a vertical line the steam pressures in pounds per square inch above atmosphere. Lay off on a horizontal line intersecting this vertical line the stroke on any convenient scale. Then steam is admitted in the straight line A B, and expands along the line B C. At the point C, the exhaust valve opens to the atmosphere. The piston returns along the line D E against a pressure of 5 lb. above that of the atmosphere. The admission valve opens again at E, and the pressure immediately rises to what it was when admitted at the point A.

Card A B C D E A is, therefore, an ideal card for this engine, but we know that no engine can give an ideal card. The corners at B, C, D, and E, are not right angles, but curves, approximately as shown on the dotted lines. The most difficult thing about the construction of this card is the



THEORETICAL INDICATOR-CARD.

plotting of the curve B C. The points on this curve may be found as follows:

In this engine the volume of steam up to the point of cut-off B is 300 cubic inches. If we expand this volume until it occupies a space of 600 cubic inches, the absolute pressure will be one-half of the initial absolute pressure of 95 + 14.7 = 109.7 lb., or 54.8 lb., and by drawing the vacuum line as shown, 14.7 lb. below the atmospheric line on the same scale as was used for laying off the gauge pressures, and at half stroke drawing a vertical line and laying off on it 54.8 lb. above the vacuum line, the point P is obtained. Similarly, if we expand 300 cubic inches until it occupies three times that volume, the absolute pressure at the point P′ will be one-third of what it was at B, or 36.6 lb. Similarly, we may get as many points on this curve as we choose, and by connecting them produce the line B C. From this card we figure the mean effective pressure just as we would from any other card.

For the case given above the mean effective pressure would be practically as obtained from the tables and the indicated horse-power would also be the same.

343. A boiler using a fuel with a calorific value of 14,000 B. t. u. per pound is shown by a test to be evaporating 8.9 lb. of water per pound of fuel used. The water is fed to the boiler at a temperature of 120° F. and the gauge pressure is 100 lb. What is the efficiency of the boiler? Give your calculations.

Ans. From the steam tables it is found that the total heat above 32° F. in a pound of saturated steam at a gauge pressure of 100 lb. is 1184.4 B. t. u. Since the water is fed into the boiler at a temperature of 120° F., it already possesses a quantity of heat above 32° F. equal to 120 — 32 = 88 B. t. u., so that there is imparted to it in the boiler, to convert it into steam at a gauge pressure of 100 lb., only 1184.4 — 88 = 1096.4 B. t. u. per pound. There being 8.9 lb. of steam formed under the given conditions for each pound of coal used, the heat put into the steam, that is, the useful work done, per pound of coal is 1096.4 × 8.9 = 9757.96 B. t. u. The combustion of the coal produces 14,000 B. t. u. per pound. Since only 9757.96 of these are used, the efficiency of the boiler is 9757.96 ÷ 14,000 = 69.7%.

344. Assuming for the boiler an efficiency of 70 per cent. and the use of a fuel that will develop 14,000 heat units (British thermal units) per pound, how many pounds of water will be evaporated per pound of fuel, the temperature of the feed water being 100° Fahr. and the working pressure 100 lb. per square inch?

Ans. Since it is assumed that the fuel develops 14,000 heat units per pound and that the efficiency of the boiler is 70 per cent. the heat available for the evaporation of water is 14,000 x 0.70 = 9,800 heat units per pound of fuel.

The quantity of heat required to turn one pound of water at 100° F. into steam at 100 lb. gauge pressure can be calculated by means of the proper formula or taken direct from a table of the Properties of Saturated Steam, such a table being given in most books on boilers. From this we find that the total heat of evaporation above 32° F. of steam at 114.7 lb. absolute pressure (= 100 lb. gauge pressure) is 1184.4 heat units. From this we must subtract the amount of heat required to raise the temperature of 1 lb. of water from 32° to 100°, the assumed feed water temperature. This is 68 heat units and 1184.4 - 68 = 1116.4 heat units. Consequently the number of pounds of water evaporated by one pound of fuel under the assumed conditions will be found by dividing 9,800, the number of heat units available for evaporation, by 1116.4, the number of heat units required to evaporate one pound of water under these conditions.

Therefore, 9800 ÷ 1116.4 = 8.78 lb. of water will be evaporated per pound of fuel used.

345. What is the "Principle of the Conservation of Energy," and how would you apply it to check up the claims made as to the results to be obtained from a new process for making gas?

Ans. The "Principle of the Conservation of Energy" is that the total energy of the universe is constant, no energy being created or destroyed in any of the processes of nature, every gain or loss in one form of energy, corresponding precisely to a loss or gain in some other form or forms. (Century Dictionary.)

This principle follows from the still broader one, that "all that exists, whether matter or force, and in whatever form, is indestructible by any finite power," the truth of which has been, and is being, more and more firmly established by all the researches of science.

From it we reason that in no case can the sum of the energies (actual and potential) possessed by the products of any combination of different forces or bodies be greater than the sum of the energies possessed by the orginal forces or bodies before they entered into combination. And in regard to machines "that it is impossible by any combination of natural forces to make a machine, whose parts being once set in motion and then left to the operation of gravity, or other similar forces, and their own mutual action, shall later return to their original positions with greater velocities" (and consequently greater energies) "than they at first possessed," or, in other words, it is impossible to make "a machine, which being put into motion, and left to itself, will in a certain time regain its original velocity, and at the same time impart to some body, originally at rest, a certain velocity."

To apply this principle to check up the claims made as to results obtained from any process for making gas it is merely necessary to determine the relation between the sums of the energies possessed by the products of the process and the sum of the energies possessed by the raw materials employed, bearing in mind that the energies possessed by the products not only can never exceed the energies possessed by the raw materials, but will never even equal them, since in making gas it is impossible to avoid losses by radiation of heat and also by heat carried away in the waste products. If, when the claims put forth are analyzed, it is seen that the total energy claimed to be available as a result of the process is greater than, or even exactly equal to, the total energy put in, these claims can safely be dismissed as absurd. In many cases it is very easy to disprove the claims made as to the results of gas making processes by a comparison between the sum of the heating values of the materials employed and that of the same values of the products, and although it may be difficult to make the comparison in some cases it will, when properly made, always tell whether the results reported are reasonable or not.

346. The inventor of a patent process for making gas claims that from 10 lb. of coal and 15 lb. of oil he can produce 1,000 cubic feet of gas with a calorific value of 440 B. t. u. per cubic foot. The calorific value of coal may be taken as 13,500 B. t. u. per pound, and that of oil as 19,000 B. t. u. per pound. How can it be shown that the above claim is impossible of realization?

Ans. When wonderful working results are claimed for a process it is always well to test the possibility of securing these results by applying the principle of the conservation of energy and determining whether or not the quantity of materials said to be used is capable of supplying the energy which it is claimed exists in the products. In doing this it must be borne in mind that no process for making gas from solid or liquid bodies can have a thermal efficiency of 100%, since some heat is required to overcome the attraction between the molecules of solid and liquid substances and convert them into gases, and also since it is impossible to avoid losses of heat by radiation and the sensible heat of the escaping waste products. The thermal efficiencies of the commonly employed processes for making gas vary from about 50% to about 80%.

According to the data given in the question the total number of heat units in the materials in the quantity in which they are employed per 1,000 cubic feet of gas is equal to $10 \times 13{,}500 + 15 \times 19{,}000 = 135{,}000 + 285{,}000 = 420{,}000$, since 10 lb. of coal with a calorific value of 13,500 B. t. u. and 15 lb. of oil with a calorific value of 19,000 B. t. u. per pound are used to make this quantity of gas. The calorific value claimed for the gas made, 440,000 B. t. u., is therefore greater by 20,000 heat units than the total amount of heat in the materials employed, and the claim is manifestly impossible of realization.

347. With gas selling at \$1.25 per 1,000 cubic feet and electric current at 11 cents per kilowatt hour, what are the comparative costs of one candle power per hour furnished by an incandescent gas light and an incandescent electric light, respectively, the cost of renewals being left out in both cases?

Ans. A 16 C. P. tungsten incandescent electric lamp will develop 16 C. P. with a consumption of 20 watts per hour, or 1.25 watts per candle power per hour. At 11 cents per kilowatt hour this will cost $\frac{1.25 \times 11}{1,000} = \frac{13.75}{1,000} = 0.0138$c. per candle power per hour. This is the maximum efficiency for electric light for domestic purposes.

A good commercial incandescent gas light will develop 20 candles per cubic foot of gas per hour, and will therefore require one-twentieth or 0.05 of a cubic foot per candle power per hour. The cost, with gas at \$1.25 per 1,000 cubic feet, is $\frac{0.05 \times 125}{1,000} = \frac{6.25}{1,000} = 0.0063$c. per candle power.

The cost of gas under the assumed conditions is therefore $\frac{1}{2.3}$ of that of electricity for the same candle power.

348. A cylindrical water tank is 25 feet high and 35 feet in diameter. What are its contents in American gallons when full? What is the weight of the water contained in it when full? What is the pressure per square foot on the bottom when full?

Ans. The area of a circle 35 feet in diameter is 962.12 square feet. Since this is the base of the cylinder and its height is 25 feet the volume will be $25 \times 962.12 = 24053$ cubic feet.

One cubic foot contains 7.48 American gallons.

$24053 \times 7.48 = 179,916.4$ American gallons contained in the cylinder or tank.

One cubic foot of water weighs 62.5 lb.

$24053 \times 62.5 = 1,503,312.5$ lb. = the weight of water in the tank.

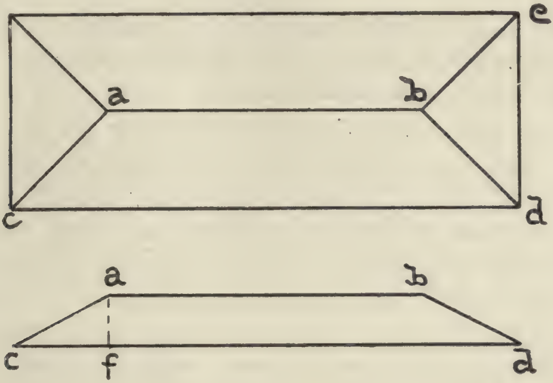
The pressure per square foot on the bottom is 62.5 (weight of a cubic foot of water) × 25 (depth of water in feet) = 1562.5 lb. per square foot.

The pressure per square foot on the base is explained thus: If we imagine a cubic foot of water weighing 62.5 lb. to be solidified and placed on the floor, the pressure on the square foot of the floor occupied by the cube will be 62.5 lb. If a similar cube of water be placed on top of the first cube, the pressure on the square foot of floor occupied by the first cube will be 2 × 62.5 = 125 lb. Twenty-five such cubes, one on top of the other, will exert a pressure of 25 × 62.5 = 1562.5 lb. on the square foot. The pressure per square foot of any liquid on the bottom of a tank is equal to the weight of a cubic foot of the liquid multiplied by the depth in feet.

349. A wagon with a body measuring 10 ft. 4 in. in length by 4 ft. 0 in. in width and 2 ft. 0 in. in depth comes for coke. How many bushels will it hold, first, when filled even with the top edges of the sides, and second, when the coke is sloped up to a ridge one foot above the top edges of the sides? Give your calculations.

Ans. The volume of the wagon body, and therefore the volume of the coke contained in the wagon when it is filled even with the top edges of the sides, is 10.33 ft. × 4 ft. × 2 ft. = 82.64 cubic feet. The volume of the standard bushel for measuring coke, which is given in the answer to question No. 10, is 1.5901 cubic feet, so the wagon when filled even with the top of the sides will hold $\frac{82.64}{1.5901} = 51.97$, or in round numbers, fifty-two bushels.

When the coke is sloped up above the sides to a ridge one foot above their top edges, there is added to the volume of the wagon box an additional volume which is that of a wedge having the dimensions shown on the sketch. The volume of a wedge is obtained by adding to the length of the edge twice the length of the base and multiplying this sum by one-sixth of the product obtained by multiplying the height by the breadth of the base. In the present instance, assuming the slope to be such that the base of the triangle a, c, f, is twice the altitude, the length of the edge, a, b, is 6.33 ft., the length of the base, c, d, is 10.33 ft., the breadth of the base, d, e, is 4 ft., and the height or altitude, a, f, is 1 ft. The volume of the wedge is therefore $[6.33 + (2 \times 10.33)] \times \frac{1}{6} (4 \times 1) = 26.99 \times 0.667 = 18.00$ cubic feet, and the total volume of coke held by the wagon when loaded in this way is $82.64 + 18.00 = 100.64$ cubic feet, or $\frac{100.64}{1.5901} = 63.29$, or in round numbers, sixty-three bushels.



SECTION VII.—MASONRY CONSTRUCTION.

350. What are the characteristics of a good building brick, and how can a brick be tested to determine whether or not it possesses these characteristics?

Ans. Baker's Treatise on Masonry Construction, page 37, contains the following paragraph: "Requisites for Good Brick. 1. A good brick should have plane faces, parallel sides, and sharp edges and angles. 2. It should be of fine, compact, uniform texture; should be quite hard, and should give a clear ringing sound when struck a sharp blow. 3. It should not absorb more than one-tenth of its weight of water. 4. Its specific gravity should be two or more. 5. The crushing strength of half brick, when ground flat and pressed between thick metal plates, should be at least 7,000 pounds per square inch."

Regularity of shape can be determined by inspection of the brick, as can also, to a certain extent, compactness and uniformity of texture. The absorptive power, which affects the durability of the brick, especially as regards its resistance to frost, can be determined by weighing the brick after it has been kept exposed in a room under ordinary atmospheric conditions for a week, and then again after it has been immersed in water for from forty to forty-eight hours and allowed to dry until all the water on the surface has evaporated, the difference between the second weight and the first one being the weight of water absorbed. The smaller the amount of water so absorbed, the greater will be the durability of the brick.

In determining the crushing strength of the brick, different methods are followed. Sometimes half brick are tested and sometimes whole ones. In some cases the surfaces to be subjected to the pressure are ground accurately to planes parallel to each other, while in other cases the surfaces are leveled up by putting on a thin coat of plaster of paris, and in still others the bricks are put into a testing machine in the rough state. The best practice is to either grind the faces or level them up by the use of plaster of paris, so that the pressure is applied equally all over the surface. These crushing tests are usually made in a hydraulic press provided with cast iron pressing surfaces, which are self-adjusting.

The test for transverse strength is about the most valuable that can be given to brick to determine its practical value. It is made by supporting the brick on two supports with thin edges placed the required distance apart and then loading it in the centre with a load which is applied by a beam with a thin edge bearing on the brick, the load required to break the brick being carefully determined. The modulus of rupture as determined by this test should be at least 1,000 pounds per square inch.

351. What is common lime and what is the raw material used in its manufacture? What is hydraulic lime and what is the raw material used in its manufacture? What is hydraulic cement and what is the raw material used in the manufacture of natural hydraulic cement?

Ans. Common lime is the substance resulting from the calcination of pure or nearly pure limestones, such as marble, chalk, etc., at a high temperature applied for a sufficient length of time to drive off the carbon dioxide, CO_2, in the limestone. It is principally calcic oxide, CaO, with from 3% to 10% of impurities such as silica, alumina, magnesia, oxide of manganese, and traces of the alkalies. It is highly caustic, with a strong affinity for water, rapidly absorbing nearly one-quarter of its own weight of this substance when brought into contact with it. This absorption produces a great elevation of temperature accompanied by an increase of from 2½ to 3 times the original volume and the reduction of the lime to an impalpable powder (slaked lime or calcic hydrate, $Ca(OH)_2$) which forms with water an unctuous paste. The paste, in common with mortar made from it, will not harden when kept under water, in damp places or out of contact with air.

Hydraulic lime is the lime made by calcining limestones containing a larger percentage of impurities than those from which common lime is obtained. If the limestone contains from 10% to 20% of clay mixed with carbonate of lime, the lime produced is said to be argillaceous, while if the limestone contains from 12% to 18% of silica, the resulting lime is said to be silicious. Hydraulic lime will slake and its paste, or a mortar made from it, will harden under water and in damp places.

Hydraulic cement is the substance obtained by calcining a mixture of clay and carbonate of lime in the proper proportions at a high, long-continued heat and then reducing the lumps produced by this calcination to a fine powder by grinding them between millstones. A paste or mortar made from hydraulic cement has the property of setting or hardening under water or in damp, moist places, and increases in strength as it increases in age.

Natural hydraulic cement is made by calcining and grinding limestones, which contain approximately the proper proportions of clay and lime, that is, from 20% to 22% of clay, and from 78% to 80% of carbonate of lime, $CaCO_3$.

352. What are the objects sought in mixing sand with lime in making lime mortar, and with cement in making cement mortar, and what are the qualities required in a sand to fit it for use in making mortar?

Ans. "Sand is mixed with lime or cement to reduce the cost of the mortar, and is added to lime also to prevent the cracking which would occur if lime were used alone. Any material may be used to dilute the mortar, provided it has no effect upon the durability of the cementing material and is not itself liable to decay. Pulverized stone, powdered brick, slag, or coal cinders may be used; but natural sand is by far the most common, although fine crushed stone, or 'stone screenings,' is sometimes employed and is in some respects better than natural sand.

"To be suitable for use in mortar, the sand should be sharp, clean, and coarse; and the grains should be composed of durable minerals, and the size of the grains should be such as to give a minimum of voids, *i. e.*, interstices between the grains.

"The usual specifications are simply: 'The sand shall be sharp, clean and coarse.'

"Sharp sand, *i. e.*, sand with angular grains, is preferred to that with round grains because (1) the angular grains are rougher and therefore the cement will adhere better; and (2) the angular grains offer better resistance to moving one on the other under compression.

"The sharpness of sand can be determined approximately by rubbing a few grains in the hand, or by crushing it near the ear and noting if a grating sound is produced; but an examination through a small lens is better. Sharp sand is often difficult to obtain, and the requirement that 'the sand shall be sharp' is practically a dead letter in most specifications.

"Clean sand is necessary for the strongest mortar, since an envelope of loam or organic matter about the sand grains will prevent the adherence of the cement. The cleanness of sand may be judged by pressing it together in the hand while it is damp; if the sand sticks together when the pressure is removed, it is entirely unfit for mortar purposes. The cleanness may also be tested by rubbing a little of the dry sand in the palm of the hand; if the hand is nearly or quite clean after throwing the sand out, it is probably clean enough for mortar. The cleanness of the sand may be tested quantitatively by agitating a quantity of sand with water in a graduated glass flask; after allowing the mixture to settle, the amount of precipitate and of sand may be read from the graduation. Care should be taken that the precipitate has fully settled, since it will condense considerably after its upper surface is clearly marked.

"Although it is customary to require that only clean sand shall be used in making mortar, a small quantity of very finely powdered clay will not materially decrease the strength of the mortar. In some instances clay to the amount of 10 per cent. of sand seems not to decrease the strength of the mortar. Mortar containing considerable clay is much more dense, plastic, and water-tight; and is occasionally convenient for plastering surfaces and stopping leaky joints. Such mortar is not affected by the presence of water.

"Coarse sand is preferable to fine, since (1) the former has less surface to be covered and hence requires less cement; and (2) coarse sand requires less labor to fill the interstices with the cement. The sand should be screened to remove the pebbles, the fineness of the screen depending upon the kind of work in which the mortar is to be used. The coarser the sand the better, even if it may properly be designated fine gravel, provided the diameter of the largest pebble is not too nearly equal to the thickness of the mortar joint.

"If the voids are filled with cement, uniform coarse grains give greater strength than coarse and fine mixed; or, in other words, for rich mortar coarse grains are more important than small voids. But if the voids are not filled, then coarse and fine sand mixed give greater strength than uniform coarse grains; or, in other words, for lean mortar a small proportion of voids is more important than coarse grains.

"As a rule, the sand ordinarily employed in making cement mortar is much too fine to give maximum strength, or to permit the use of a minimum amount of cement.

"The smaller the proportion of voids, *i. e.*, the interstices between the grains of the sand, the less the amount of cement required, and consequently the more economical the sand.

"Very fine sand makes a much weaker mortar than coarse sand, and natural sands vary considerably in the proportion of voids and consequently differ in the amount of cement required to produce any particular strength. Therefore before adopting a sand for a work of any considerable magnitude, all available sands should be carefully examined with reference to (1) their effects upon the strength of the mortar, (2) their per cent. of voids or the amount of cement required with each, and (3) their cost. If mortar of any particular strength is desired, the proportion of cement should be adjusted according to the fineness and voids of the best available sand." (Baker's Masonry Construction.)

353. Give the characteristics of a good mortar lime, and describe the preparation and use of lime mortar for brickwork construction with the precautions to be observed to insure the greatest possible strength for the finished work.

Ans. "Good lime may be known by the following characteristics:

"1. Freedom from cinders and clinkers, with not more than 10 per cent. of other impurities, as silica, alumina, etc. 2. Chiefly in hard lumps with but little dust. 3. Slakes readily in water, forming a very fine smooth paste, without any residue. 4. Dissolves in soft water, when this is added in sufficient quantities. These simple tests can be readily applied to any sample of lime.

"The lime which, as indicated above, should be in hard lumps with but little dust, must first be slaked and made into a paste. The ordinary process of slaking lime consists in placing the lumps in a layer 6 or 8 inches deep in either a water-tight box, or a basin formed in the sand to be used in mixing the mortar, and pouring upon the lumps a quantity of water 2½ to 3 times the volume of the lime. Sand in proper proportions is spread evenly over the paste thus made, and the ingredients are thoroughly mixed with a shovel or a hoe, usually the latter, a little water being added occasionally if the mortar is too stiff. It is best to mix the mortar stiff and thoroughly drench the brick before laying, as mixing the mortar thin interferes with its setting, and still more with its adhesion to the brick. Watery mortar also contracts excessively in drying (if it ever does dry), causing undue settlement and, possibly, cracks or distortion. Wetting the brick before laying also removes from the surface dust which otherwise would prevent perfect adhesion.

"Owing to its not setting when excluded from the air, common lime mortar should never be used for very thick walls, in the interior of which it will not harden, nor under water, nor in soil that is constantly wet; and, owing to its weakness, it is unsuitable for structures requiring great strength, or subject to shock.

"In slaking the lime the quantity of water used should be carefully regulated. Too much water reduces the slaked lime to a semi-fluid condition and injures its binding qualities. If too little is used in the first place and then more added after the slaking is well under way, and a portion of the lime already reduced to powder, the temperature is suddenly depressed and the lime chilled, rendering it granular and lumpy. It is also very important that the lime should not be stirred while slaking. The essential point is to secure the reduction of all the lumps. The common limes contain impurities which prevent a thorough, uniform, and prompt slaking of the entire mass; hence all the lime necessary for any required quantity of mortar should be slaked at least one day before being incorporated with the sand, to avoid all danger to the masonry from subsequent enlargement of volume and change of condition. The paste should be protected from the air by being covered with sand until used.

"As a paste of common lime sets or hardens very slowly, even in the open air, unless it be subdivided into very small particles or films, it is important that the lime paste in common mortar should be but slightly in excess of what is sufficient to coat all the grains of sand and to fill the voids between them. If this limit be exceeded the strength of the mortar will be impaired. With most sands the proper proportions will be from 2.5 to 3 volumes of sand to 1 volume of lime paste. Generally, if either less or more sand than this be used, the mortar will be injured, in the former case from excess of lime paste, and in the latter from porosity." (Baker, Masonry Construction.)

For precautions as to the quality of sand, see answer to question No. 352.

354. What distinguishes "Portland" cement from "Rosendale" and other "natural" cements?

Ans. Some hydraulic cements are made from rock which contains approximately the desired proportions of limestone and clay. These are known as "natural cements," and are sometimes called Rosendale cements, from a town in New York.

In the manufacture of some hydraulic cements the limestone and clay are mixed artificially, and in definite proportions, before burning, and the product of this process of preparation is known as "Portland cement." This cement, being a mixture of exact and predetermined proportions of the necessary materials, is a more valuable building material than most of the natural cements.

Portland cement takes its name from the resemblance artificial stone made of it bears to stone found on Portland Island, south of England. The original Portland cement was a natural cement, but the name is now used to distinguish the cements made from an artificially prepared mixture of ingredients as detailed above.

From good authority we have the statement that cement owes its hydraulic quality to certain silicates and aluminates of lime formed during the burning, by the action of the heat, and which possess the property of taking up water of hydration and crystalizing to a hard and compact mass.

355. What is Portland cement, how is it made, and what tests should be applied to any given sample to determine its quality?

Ans. The name Portland cement was first given to a natural hydraulic cement prepared by calcining a limestone containing from 20% to 22% of clay composed of 1½ to 2 parts of silica to one of alumina and 78% of carbonate of lime. At present the name is practically confined to a class of artificial hydraulic cements made by thoroughly mixing together in suitable proportions (approximately as above) clay and finely pulverized carbonate of lime (either chalk, marl or compact limestone), burning the mixture in kilns at a high heat and then grinding the burnt product to fine powder between ordinary millstones.

The superiority of Portland cement appears to depend in great measure upon the presence of the double silicate of lime and alumina, which is formed only at a high heat. The weight of Portland cement, as well as its hydraulic energy and its ultimate strength and hardness, is increased by augmenting (within the limit of vitrification) the intensity and duration of the heat employed in burning. The initial hydraulic activity, however, is diminished by high burning, so that the best Portland cements are slowest in setting. A cement weighing 100 lb. to the bushel may be burnt so as to weigh

125 lb. to the bushel, and its strength will be nearly doubled thereby.

"The properties of a cement which are usually examined to determine its constructive value are: (1) color, (2) weight, (3) activity, (4) soundness, (5) fineness, and (6) strength. The last three are the most important.

"Color. The absolute color of a cement indicates but little. With Portland cement, gray or greenish gray is generally considered best; bluish gray indicates a probable excess of lime, and brown an excess of clay. An undue proportion of the under-burned material is generally indicated by a yellowish shade, with a marked difference between the color of the hard-burned, unground particles retained by a fine sieve and the finer cement which passes through the sieve.

"Weight. For any particular cement the weight varies with the degree of heat in burning, the degree of fineness in grinding and the density of packing. Other things being the same, the harder-burned varieties are the heavier. The finer a cement is ground the more bulky it becomes and consequently the less it weighs. Hence, light weight may be caused by laudable fine grinding or by objectionable under-burning.

"The weight per unit of volume is usually determined by sifting the cement into a measure as lightly as possible and striking the top level with a straight edge. In careful work the height of fall is specified. The weight per cubic foot is neither exactly constant, nor can it be determined precisely, and for the practical purpose of the user is of very little service in determining the value of a cement. However, it is often specified as one of the requirements to be fulfilled.

"The following values, determined by sifting the cement with a fall of three feet into a box having a capacity of one-tenth of a cubic foot, may be taken as fair averages for ordinary cements. The difference in weight for any particular kind is mainly due to a difference in fineness:

Portland,	English and German....	77 to 90	lb.	per	cubic foot.
"	fine ground French.....	69	"	"	"
"	American.............	95	"	"	"

"Test of activity. 'To test hydraulic activity, mix cement with 25 to 30 per cent. of its weight of clean water having a temperature of between 65° F. and 70° F., to a stiff plastic mortar, and make one or two cakes or pats 2 or 3 inches in diameter and about $\frac{1}{2}$ in. thick. As soon as the cakes are prepared, immerse in water at 65° F., and note the time required for them to set hard enough to bear respectively a $\frac{1}{12}$ in. wire loaded to weigh $\frac{1}{4}$ lb., and a $\frac{1}{24}$ in. wire loaded to weigh 1 lb. When the cement bears the light weight, it is said to have begun to set; when it bears the heavy weight, it is said to have entirely set.' Cements, however, will increase in hardness long after they can just bear the heavy wire. The activity of the cement is measured by the time which elapses between the time when the first weight is supported and that when the second is just borne."

A committee of the American Society of Civil Engineers recommended the following tests for soundness (or the property of not expanding, or contracting, or checking in setting), fineness and tensile strength.

"It is recommended that tests for hydraulic cement be confined to methods for determining fineness, liability to checking or cracking, and tensile strength; and for the latter, for tests of seven days and upwards, that a mixture of 1 part of cement to 1 part of sand for natural cements, and 3 parts of sand for Portland cements, be used, in addition to trials of neat cement. The quantities used in the mixture should be determined by weight.

"Sampling. There is no uniformity of practice among engineers as to the sampling of the cement to be tested, some testing every tenth barrel, others every fifth, and others still every barrel delivered. Usually, where cement has a good reputation and is used in large masses, such as concrete in heavy foundations or in the backing or hearting of thick walls, the testing of every fifth barrel seems to be sufficient; but in very important work, where the strength of each barrel may in a great measure determine the strength of that portion of the work where it is used, or in the thin walls of sewers, etc., every barrel should be tested, one briquette being made from it.

"In selecting cement for experimental purposes, take the samples from the interior of the original packages at sufficient depth to insure a fair exponent of the quality, and store the same in tightly closed receptacles impervious to light or dampness until required for manipulation, when each sample of cement should be so thoroughly mixed, by sifting or otherwise, that it shall be uniform in character throughout its mass.

"Checking or Cracking. The test for checking or cracking is an important one, and, though simple, should never be omitted. It is as follows:

"Make two cakes of neat cement 2 or 3 inches in diameter, about ½ inch thick, with thin edges. Note the time in minutes that these cakes, when mixed with water to the consistency of a stiff plastic mortar, take to set hard enough to stand the wire test recommended by General Gillmore, $\frac{1}{12}$ inch diameter wire loaded with one-fourth of a pound, and $\frac{1}{24}$ inch loaded with 1 pound. One of these cakes, when hard enough, should be put in water and examined from day to day to see if it becomes contorted or if cracks show themselves at the edges, such contortions or cracks indicating that the cement is unfit for use at that time. In some cases the tendency to crack, if caused by the presence of too much unslaked lime, will disappear with age. The remaining cake should be kept in the air and its color observed, which, for a good cement, should be uniform throughout (yellowish blotches indicating a poor quality), the Portland cements being of a bluish-gray, and the natural cements being light or dark according to the character of the rock of which they are made. The color of the cements when left in the air indicates the quality much better than when they are put in water.

"Fineness. The strength of a cement depends greatly upon the fineness to which it is ground, especially when mixed with a large dose of sand. It is therefore recommended that the tests be made with cement that has passed through a No. 100 sieve (10,000 meshes to the square inch), made of No. 40 wire (Stubs's wire gauge). The results thus obtained will indicate the grade which the cement can attain, under the condition that it is finely ground, but it does not show whether or not a given cement offered for sale shall be accepted and used. The determination of this question requires that the tests should also be applied to the cement as found in the market. Its quality may be so high that it will stand the tests, even if very coarse and granular; and, on the other hand, it may be so low that no amount of pulverization can redeem it. In other words, fineness is no sure indication of the value of a cement, although all cements are improved by the fine grinding. Cement of the better grades is now usually ground so fine that only from 5 to 10 per cent. is rejected by a sieve of 2,500 meshes per square inch, and it has been made so fine that only from 3 to 10 per cent. is rejected by a sieve of 32,000 meshes per square inch. The finer the cement, if otherwise good, the larger dose of sand it will take and the greater its value.

"Sieves. For ascertaining the fineness of cement, it will be convenient to use three sieves; viz., No. 50 (2,500 meshes to the square inch), wire to be of No. 35 Stubs's wire gauge; No. 74 (5,476 meshes to the square inch), wire to be of No. 37 Stubs's wire gauge; No. 100 (10,000 meshes to the square inch), wire to be No. 40 Stubs's wire gauge. The object is to determine by weight the percentage of each sample that is rejected by these sieves, with a view not only of furnishing the means of comparison between tests made of different cements by different observers, but indicating to the manufacturer the capacity of his cement for improvement in a direction always and easily within his reach.

"For ascertaining the fineness of sand, two sieves are recommended; viz., No. 20 (400 meshes to the square inch), wire to be of No. 28 Stubs's wire gauge; No. 30 (900 meshes to the square inch), wire to be of No. 31 Stubs's wire gauge.

"Tensile Strength. The tests should be applied to the cements as offered for sale. The following table gives the average minimum and maximum tensile strength per square inch which some good cements have attained:

Age of Mortar when Tested.	Average Tensile Strength in Pounds per Square Inch. Portland.	
	Min.	Max.
Clear Cement.		
1 day—1 hour, or until set, in air, the remainder of the time in water....	100	140
1 week—1 day in air, the remainder of the time in water..............	250	550
4 weeks—1 day in air, the remainder of the time in water..............	350	700
1 year—1 day in air, the remainder of the time in water.............	450	800
1 Part Cement to 3 Parts Sand by weight.		
1 week—1 day in air, the remainder of the time in water.............	80	125
4 weeks—1 day in air, the remainder of the time in water.............	100	200
1 year—1 day in air, the remainder of the time in water.............	200	350

"If satisfactory results are obtained with a full dose of sand, the trials need go no further. If not, the coarser particles should be excluded by using a No. 100 sieve in order to determine approximately the grade the cement would take if ground fine, for fineness is always attainable, while inherent merit may not be.

"Standard Sand. The question of a standard sand seems one of great importance, for it has been found that sands looking alike and sifted through the same sieves give results varying within rather wide limits.

"The material that seems likely to give the best results is the crushed quartz used in the manufacture of sandpaper. It is a commercial product, made in large quantities and of standard grades, and can be furnished of a fairly uniform quality. It is clean and sharp, and although the present price is somewhat excessive (three cents per pound), it is believed that it can be furnished in quantity for about $5 per barrel of 300 pounds. As it would be used for tests only, for purposes of comparison with the local sands and with tests of different cements, not much of it would be required. The price of the German standard sand is about $1.25 per 112 lb., but the article, being washed river sand, is probably inferior to crushed quartz. Crushed granite could be furnished at a somewhat less rate than quartz, and crushed trap for about the same as granite ; but no satisfactory estimate has been obtained for either of these.

"The use of crushed quartz is recommended by your committee, the degree of fineness to be such that it will pass a No. 20 sieve and be caught on a No. 30 sieve." (Baker, Masonry Construction.)

Unless a testing machine is available it is not always possible to make the tests for strength, and in the ordinary work for which Portland cement is employed in gas works these tests are not really necessary if a good brand of cement is purchased. The tests for fineness and soundness are, however, very easily made, and the latter should always be made on any cement that is to be used, especially in foundation work.

356. What is Rosendale or Utica cement, how is it made, and what tests should be applied to any given sample to determine its quality ?

Ans. Rosendale or Utica cement, also called natural cement, is made from limestones composed of carbonate of lime, carbonate of magnesia and clay. The limestone is burned in a kiln and then ground to a fine powder. "Any magnesian limestone containing as high as 60 per cent. of carbonate of magnesia may be presumed to be capable of yielding hydraulic cement of greater or less value, if properly burned, no matter whether clay be present or not."

Cement should be tested for fineness, liability to cracking and tensile strength.

"Fineness: 90 to 95 per cent. of the cement should pass through a sieve of 2,500 meshes per square inch. Other qualities being equal, the finer a cement is ground the greater is its value.

"Checking or Cracking. The test for checking or cracking is an important one, and, though simple, should never be omitted. It is as follows :

"Make two cakes of neat cement 2 or 3 inches in diameter, about $\frac{1}{2}$ inch thick, with thin edges. Note the time in minutes that these cakes, when mixed with water to the consistency of a stiff, plastic mortar, take to set hard enough to stand the wire test recommended by General Gillmore, $\frac{1}{12}$ inch diameter wire loaded with one-fourth of a pound, and $\frac{1}{24}$ inch loaded with 1 pound. One of these cakes, when hard enough, should be put in water and examined from day to day to see if it becomes contorted or if cracks show themselves at the edges, such contortions or cracks indicating that the cement is unfit for use at that time. In some cases the tendency to crack, if caused by the presence of too much unslaked lime, will disappear with age. The remaining cake should be kept in the air and its color observed, which, for a good cement, should be uniform throughout (yellowish blotches indicating a poor quality), the natural cements being light or dark according to the character of the rock of which they are made. The color of the cements when left in the air indicates the quality much better than when they are put in water.

" Tensile Strength. The tests should be applied to the cement as offered for sale. The following table gives the average minimum and maximum tensile strength per square inch which some good cements have attained :

Age of Mortar when Tested.	Average Tensile Strength in Pounds per Square Inch. Rosendale.	
Clear Cement.	*Min.*	*Max.*
1 day—1 hour, or until set, in air, the remainder of time in water	40	80
1 week—1 day in air, the remainder of time in water	60	100
4 weeks—1 day in air, the remainder of time in water	100	150
1 year—1 day in air, the remainder of time in water	300	400
One Part Cement and One Part Sand by Weight.		
1 week—1 day in air, the remainder of the time in water	30	50
4 weeks—1 day in air, the remainder of the time in water	50	80
1 year—1 day in air, the remainder of the time in water	200	300

"If satisfactory results are obtained with a full dose of sand, the trials need go no further. If not, the coarser particles should be excluded by using a No. 100 sieve, in order to determine approximately the grade the cement would take if ground fine, for fineness is always attainable, while inherent merit may not be.

"Weight. For any particular cement the weight varies with the degree of heat in burning, the degree of fineness in grinding, and the density of packing. Other things being the same, the harder-burned varieties are the heavier. The finer a cement is ground the more bulky it becomes, and consequently the less it weighs. Hence, light weight may be caused by laudable fine grinding or by objectionable underburning.

"The weight per unit of volume is usually determined by sifting the cement into a measure as lightly as possible, and striking the top level with a straight edge. In careful work the height of fall is specified. The weight per cubic foot is neither exactly constant nor can it be determined precisely, and for the practical purpose of the user is of very little service in determining the value of a cement. However, it is often specified as one of the requirements to be fulfilled.

"The weight of Rosendale cement, determined by sifting the cement with a fall of three feet into a box having a capacity of one-tenth of a cubic foot, is 49 to 56 lb. per cubic foot. The difference in weight for any particular kind is mainly due to a difference in fineness.

"Ulster Co. Rosendale cement weighs 300 lb. per barrel net; Akron, Milwaukee, Utica and Louisville Rosendales weigh 265 lb. per barrel net." (Baker, Masonry Construction.)

357. Describe the preparation and use of cement mortar for brick work, with the precautions to be observed to secure uniformity and strength.

Ans. A paste of good hydraulic cement hardens simultaneously and uniformly throughout the mass, and its strength is impaired by any addition of sand. The relative quantities of sand and cement depend somewhat upon the kind of work and upon the conditions of the ingredients when measured. For ordinary use it is customary to add as much sand as is possible without making the mortar porous. The proportions may vary from one part of cement and two parts of sand to one part of the former and four of the latter.

The proportions of sand and cement are generally measured by volume. In actual work the cement is usually delivered in barrels, and consequently the most convenient unit for the cement is a commercial barrel, while it is most convenient to measure sand loose.

When the mortar is required in small quantities, as for use in ordinary masonry, it is mixed about as follows: About half the sand to be used in a batch of mortar is spread evenly over the bed of the mortar-box and then the dry cement is spread evenly over the sand; and finally, the remainder of the sand is spread on top. The sand and cement are then mixed with a hoe, or by turning and re-turning with a shovel. It is very important that the sand and cement be thoroughly mixed.

The dry mixture is then shoveled to one end of the box, and water is poured into the other end. An excess of water is better than a deficiency, particularly when a very energetic cement is used, as the capacity of this substance for solidifying water is great. The sand and cement are then drawn down with a hoe, small quantities at a time, and mixed with the water until enough has been added to make a good stiff mortar. This should be vigorously worked with a hoe for several minutes to insure a good mixture. The mortar should then leave the hoe clean when drawn out of it, and very little should stick to the steel.

Hydraulic cements are better and attain a greater strength under water than in the open air; in the latter, owing to the evaporation of the water, the mortar is liable to dry instead of setting. The difference is very marked in hot, dry weather. If cement mortar is to be exposed to the air, it should be shielded from the direct rays of the sun and kept moist by sprinkling or otherwise.

Grout is a thin or liquid mortar of lime or cement. The interior of a wall is sometimes laid up dry, and the grout, which is poured on top of the wall, is expected to find its way downwards and fill all voids, thus making a solid mass of the wall.

Grout should never be used when it can be avoided. If made thin, the water only slowly dries out of the wall; and if made thick, the grout fills only the upper portion of the wall. To get the greatest strength, the mortar should have only enough water to make a stiff paste—the less water the better. If the mortar is stiff, the brick or stone should be dampened before laying; else the brick will absorb the water from the mortar before it can set, and thus destroy the adhesion of the mortar. (Baker, Masonry Construction.)

358. What precautions must be taken when laying brick in cement mortar to secure the greatest strength in the finished work?

Ans. In laying bricks in cement mortar the joints should be made as thin as it is possible to have them and at the same time give a uniform bearing to the bricks; all joints should be filled with mortar and to insure adhesion between the mortar and the bricks the bricks should be wet when put into the wall.

Thinness of the joints is required because the mortar is weaker than the brick and a thick joint is weaker than a thin one, even under the best conditions, and also because in outside walls the mortar in thick joints is more exposed to deterioration from the action of the weather.

If the joints are not well filled the strength of the wall is obviously reduced. To secure thoroughly filled joints the bricks "should not be merely *laid*, but every one should be rubbed and pressed down in such a manner as to force the mortar into the pores of the brick and to produce the maximum adhesion. For the best work it is specified that the brick shall be laid with a 'shove joint,' that is, that the brick shall be first laid so as to project over the one below, and be pressed into the mortar and then shoved into its final position.

"Since brick have great avidity for water, it is best to dampen them before laying. To get the greatest strength the mortar should have only enough water to make a stiff paste—

the less water the better. If the mortar is stiff and the brick dry, the latter absorb the water so rapidly that the mortar does not set properly, and will crumble in the fingers when dry. Neglect in this particular is the cause of most of the failures in brick work. Since an excess of water in the brick can do no harm, it is best to thoroughly drench them with water before laying. Wetting the brick before laying will also remove the dust from the surface, which otherwise would prevent perfect adhesion." (Baker, Masonry Construction.)

359. What considerations would determine your choice between lime mortar and cement mortar for use in any given job of brick or stone masonry?

Ans. Since there are certain conditions under which lime mortar will not harden and other conditions which are unfavorable to the durability of cement mortar, the main consideration in determining the choice between the two in any given case is that of the conditions to which the brickwork is to be subjected.

Lime mortar will not harden when cut off from access of air, or when exposed to water or to moist earth or air. It should, therefore, never be used in masonry work underground, in damp places and in thick walls, to the middle of which the air cannot penetrate, all such masonry being laid with cement mortar. Under the head of damp places must be included the top four or five courses of all brick walls, which should always be laid with cement mortar, even though lime mortar is employed for the rest of the work.

Cement mortar, on its part, will not be durable when exposed to even moderate heat and so deprived of the moisture that is necessary to enable it to set and grow harder with age. It must, therefore, give place to lime mortar in that part of the brickwork of retort stacks, boiler settings and chimneys where it is not necessary to use fire clay on account of exposure to high heat.

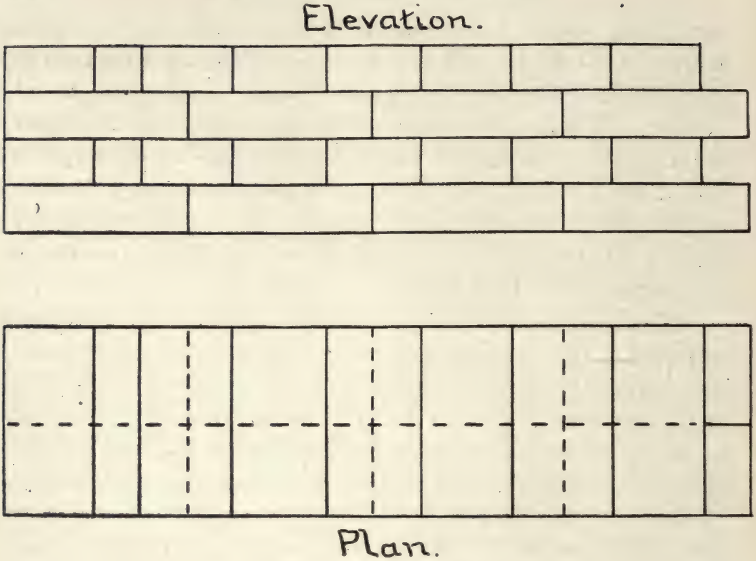
When the conditions are such that either kind of mortar will set, the most important consideration in determining the choice between them is the strength that the masonry is required to have. Lime mortar is not as strong as cement mortar, and the latter must therefore be used whenever the strength requirements are greater than can be met by the former. It is also necessary to use cement mortar in masonry subject to vibration, such as the foundations of steam engines and other moving machinery, as in such masonry it is necessary to have the adhesion between the mortar and the brick or stone as strong as possible, and cement mortar is stronger in this respect than lime mortar.

Where lime mortar will set satisfactorily and is sufficiently strong for the requirements, the consideration that usually determines the choice is cheapness, and as a rule lime mortar is the cheapest. But by properly proportioning the amount of sand used with cement, it is often possible to make a mortar that is as cheap as lime mortar, and stronger. The cement mortar can also be cheapened by mixing ~~with it lime~~ paste, and if the amount of this paste is not made greater than one-fourth of the combined amount of lime and cement, the resulting mortar will be stronger and better than lime mortar. But when there is not much difference between the cost of lime mortar and cement mortar without any admixture of lime, it is better to use the latter, since it is much more durable and will cost less for repairs.

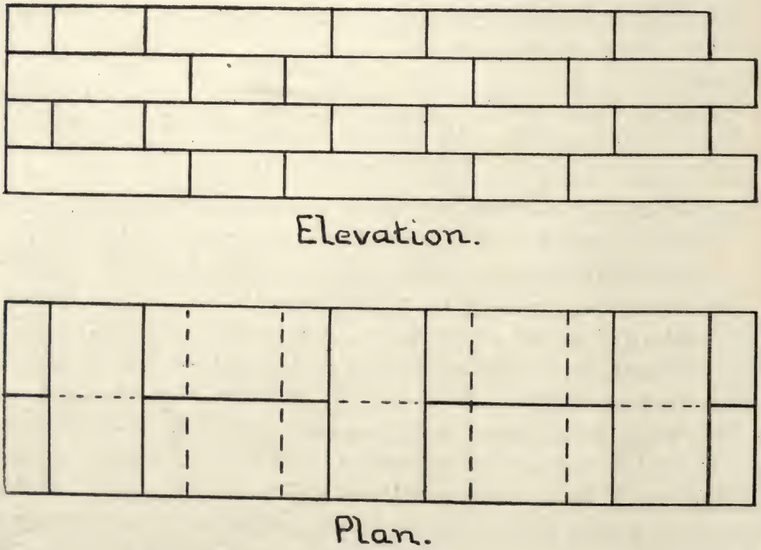
360. What is meant by the term "bond" as used in speaking of brick-work? What is English Bond? What is Flemish Bond? Give sketches as well as descriptions.

Ans. "Bond" in brick-work denotes the uniform system in accordance with which the bricks are placed in the wall.

English Bond is a system in which all the bricks in any one course are either headers (bricks laid with their length perpendicular to the face of the wall), or stretchers (bricks laid with their length parallel to the face of the wall.) Sometimes the courses of headers and stretchers alternate, but usually there are several courses of stretchers for each course of headers. In ordinary walls the proportion of stretcher courses to header courses is sometimes made as high as seven to one, but this makes a wall which is weak transversely, since stretchers give longitudinal strength and headers transverse strength. For the



ENGLISH BOND.



FLEMISH BOND.

walls of gas works buildings, at least one course in four should be laid in headers. One course of headers in three courses gives equal strength longitudinally and transversely.

In laying bricks in English Bond, care must be taken to make the vertical joints in the header courses thin, so that the two headers and the vertical joint between them will not take up a greater length than the stretcher, and prevent the correct breaking of the joints by one-quarter of a brick.

Flemish Bond is a system in which the bricks in each course are alternately headers and stretchers, the outer end of each header lying on the middle of a stretcher in the course below. There are the same number of vertical joints in each course and there is, therefore, nothing to prevent the proper breaking of these joints. Brick-work laid in Flemish Bond presents a neater appearance than does that laid in English Bond, but the latter is stronger than the former.

361. Define the terms "Ashlar" and "Rubble" as used in designating different kinds of masonry.

Ans. Baker, Treatise on Masonry Construction, following the recommendations of a Committee of the American Society of Civil Engineers, gives these definitions:

"Ashlar. Cut-stone masonry or masonry composed of any of the various kinds of cut-stone." (Cut-stone he has previously defined as "all squared stones with smoothly-dressed beds and joints."). "From its derivation ashlar apparently means large square blocks; but practice seems to have made it synonymous with 'cut stone,' and this secondary meaning has been retained for convenience.

"Broken Ashlar, ... in which the joints are not continuous.

"Small Ashlar, in which the stones are less than one foot thick. Term not often used.

"Rough Ashlar. A term sometimes given to squared-stone masonry when laid as range work; 'but it is more logical and more expressive to call such masonry squared range-work.'

"Squared-stone Masonry. Work in which the stones are roughly squared and roughly dressed on beds and joints. The distinction between squared-stone masonry and ashlar lies in the degree of closeness of the joints. According to the report of the Committee of the American Society of Civil Engineers, 'when the dressing on the joints is such that the distance between the general planes of the surface of the adjoining stones is one-half inch or more, the stones properly belong to this class;' nevertheless, such masonry is usually classed as ashlar or cut-stone masonry.

"Quarry-faced Masonry. That in which the face of the stone is left as it comes from the quarry.

"Pitch-faced Masonry. That in which the face of the stone is roughly dressed.

"Range-work. Masonry in which the course is of the same thickness or rise throughout.

"Broken Range-work. Masonry in which the courses are not continuous throughout.

"Random-work. Masonry which is not laid in courses at all.

"Rubble Masonry. Masonry composed of unsquared stone.

"Uncoursed Rubble. Masonry composed of unsquared stones laid without any attempt at regular courses.

"Coursed Rubble. Unsquared stone masonry which is levelled off at specified heights to an approximately horizontal surface. It may be specified that the stone shall be roughly shaped with the hammer, so as to fit approximately."

Professor L. M. Haupt, in a paper read before the Engineers' Club of Philadelphia, says:

"Another authority defines ashlar to be composed of 'stones dressed and pitched well and properly so that the *face* of each be a polygon of straight sides not to exceed *six* in number.' This is called *broken* ashlar; but if ashlar be *squared* stone, as elsewhere defined, this class must be excluded; and since it is more than rubble, having the *joints dressed*, it must belong to the genera of 'cut-stone;' yet according to the definition given by the Committee of the American Society of Civil Engineers, the joints should be at right angles or squared, which they are not, hence it is desirable to make a distinction between ashlar and 'cut-stone' by omitting the word *squared* from the definition of the latter, and calling the work just described *dressed rubble.* By so doing it is excluded from the species ashlar, yet included in the genera 'cut-stone.'

"It would appear that the definitions based on the relative position and kind of joints would preserve the distinction between the two grand divisions of ashlar and rubble. So long as the stones are 'squared,' that is, having beds and vertical joints at right angles to each other, the masonry built of them is *ashlar*, whether the courses be continuous or not. If continuous and of equal height it is '*regular ashlar*;' if discontinuous it is '*broken range*,' or '*random ashlar*.' (These terms are practically synonymous.) If continuous but of unequal height, it is simple *range-work* or *block-in-course.*

"If the stones are *not* '*squared*,' but have hewn joints perpendicular to the face, and making any angles with each other, it is '*dressed rubble*,' and if unhewn or in a natural state, simply '*rubble*.' The face of 'dressed rubble' may be hewn, pitched, or rough."

These two authorities therefore practically agree as to the definition of ashlar, but disagree as to that of "cut-stone" and the making of ashlar synonymous with cut-stone. Neither does Professor Haupt recognize the distinction between ashlar and squared-stone masonry, while he gives the name of "dressed rubble" to a class of masonry that does not seem to be mentioned at all by Baker, probably because it is not very common. Still the main distinction between the two species is the same with both authorities, and is that ashlar is masonry composed of "squared" stones; and rubble, that composed of "unsquared" stones.

362. What are the relative advantages of brick and stone masonry for building construction?

Ans. "Brick-work is superior to stone masonry in several respects, as follows: 1. In many localities brick is cheaper than stone, since the former can be made near by, while the latter must be shipped. 2. As brick can be laid by less skillful masons than stone, it costs less to lay it. 3. Brick is more easily handled than stone, and can be laid without any hoisting apparatus. 4. Brick requires less fitting at corners and openings. 5. Brick masonry is less liable to great weakness through inaccurate dressing or bedding. 6. Brick-work resists fire better than limestone, granite, or marble, sandstone being the only variety of stone that can compare with brick in this respect. 7. Good brick stands the effect of weathering and of the acids in the atmosphere better than sandstones, and in durability even approaches some of the harder stones. 8. All masonry fails when the mortar in its joints disintegrates or becomes dislodged; therefore, brick masonry will endure the vicissitudes of the weather as well as stone masonry, or even better, since the former usually has thinner joints.

"Brick-work is not as strong as ashlar masonry, but costs less; while it is stronger and costs more than ordinary rubble." (Baker, Masonry Construction.)

The best grades of stone have greater compressive strength and durability than brick and are better for massive work, such as heavy abutments and piers for bridges and large foundations. In comparatively thin walls, however, a better bond can be obtained with brick than with stone, and in such work the use of stone has been almost entirely abandoned in favor of brick except when the stone is employed for the purpose of ornament. In the class of buildings needed about gas works brick masonry is given the preference to stone masonry for the reasons stated in the quotation given above, except in places where good stone can be obtained either on, or very close to, the site of the works.

363. Describe the proper method of preparing and putting in a cement and broken stone concrete for foundations in dry or nearly dry earth.

Ans. The stone used in making concrete should be clean and of such a size as to pass in any direction through a 2½-inch ring. The sand should be clean, sharp and coarse. A coarser sand than that used for making mortar for brick-work can be employed to advantage for concrete. The proportions of the ingredients depend upon the strength required and upon the average size of the pieces of stone and of the grains of sand used, but, under ordinary conditions, the following proportions make a good concrete:

1 part of Portland cement.
2 parts of sand.
5 parts of broken stone.

Broken slag or coarse gravel, if entirely free from loam, may be substituted for the broken stone, and even when the latter is used, one or two parts of gravel may be added to the mixture as given above without decreasing the strength of the concrete.

For mixing the concrete a platform of plank about 10 × 16 feet should be laid. If the cement and sand are to be mixed wet, before being put on the stone, a mortar box should be placed at one end of this platform. Measuring boxes to measure the sand and broken stone should be provided. These are made with four sides only, being open both at the top and bottom. They may be either of one barrel capacity, or the one for the sand may be of two barrel capacity and that for the stone of five barrel capacity, if the mixture is to be as above 1 to 2 to 5, and should be provided with handles so that they can be easily lifted and set to one side after the material has been measured.

The sand and cement should be measured in the mortar box and the stones measured and placed on the platform at the foot of the box in a layer about 6 in. to 8 in. thick. The sand and cement are mixed in the manner described in the answer to question No. 357, the stone is wet and the mortar spread in an even layer on top of it. The whole mass is then turned over a sufficient number of times to cause the stone and mortar to be thoroughly mixed together. During this part of the operation care should be taken to really turn the mass instead of merely shoveling it from one place to another. If properly handled two or three turnings should be sufficient to produce thorough mixture.

Sometimes the cement and sand are mixed and spread on the wet stone in a dry state, the whole mass being then turned over once to mix the stone and cement. Water is then added while the mass is being turned a second time, and the turning continued until the mixture is completed. When this method is followed there is no need of a mortar box, the cement and sand being mixed on the platform.

In either case it is important not to use too much water, since wet concrete cannot be compacted by ramming. The proper quantity of water to be used should be determined by experimenting with the first two or three batches made, and the same amount should thereafter be used for each batch unless the temperature and humidity of the atmosphere change decidedly, in which case the amount of water will have to be varied to suit the changed conditions.

When thoroughly mixed the concrete should be put in barrows, carried to the excavation, dumped quietly into place and then rammed until the moisture appears on the surface. In no case should it be thrown into place with shovels, or dropped from any height, since the result of such treatment is to separate the stone and mortar and prevent the formation of a solid block of concrete.

In preparing the excavation the earth at the bottom should not be disturbed, and should it be loosened it must be rammed until firm. Where soft or yielding earth or sand occurs, the bottom should be planked and the concrete laid on this planking. The concrete should be laid in layers of not less than 5 in. nor more than 9 in. When joined to old work this should be carefully cleaned, wetted and dusted with dry cement.

364. What is reinforced concrete? Describe the method employed in building it up and state some of the purposes for which it is suitable.

Ans. Reinforced concrete is concrete which has been strengthened by the imbedding in it of what may be called a skeleton of steel. This skeleton may be built up of rods, bars, or other shapes of structural steel, or formed of wire netting, expanded metal or corrugated sheets, or of a combination of either of the last three with rods. Each special form of construction is, to a certain extent, covered by patents and has its advocates. The increase of strength given by the steel skeleton enables the concrete to be made thinner for the same strength, and also to be used for tensile strains, a use for which ordinary concrete has very little value.

In building up structures of reinforced concrete, the steel skeleton is first put in place and then the concrete is filled in around it in the usual manner. In forming the skeleton it is not necessary to join the ends of the different pieces of steel together, it being sufficient to lap these ends for a greater or less distance, according to the cross section, the adhesion between the concrete and the metal being as great, if the proper lap is given, as the strength of the metal. The framework is so placed with reference to the cross section of the concrete and the forces to be resisted as to lie in the position subject to the greatest tensile strains under the conditions of use for which the work is designed.

Reinforced concrete is especially suitable for the arches between the floor beams in fireproof construction, such as the stage floors of retort houses or any of the floors in gas works buildings. It is also used in the construction of underground tanks, and of coal pockets and sheds. It can be used in any part of the superstructure of any building as a substitute for ordinary masonry or concrete, examples of buildings of different classes having been constructed entirely of reinforced concrete. By its use it is possible to accomplish with ordinary labor almost all the work for which brick and stone masons are generally employed, and the use of the latter can be dispensed with if they are inclined to insist upon onerous conditions in regard to wages or extent of a day's work.

365. How do concrete and brickwork compare in tensile strength and resistance to crushing?

Ans. The tensile strength of brickwork is dependent upon the adhesive power of the mortar to the brick. According to a table given in Baker's Masonry Construction, the adhesive strength of Portland cement mortar, made with 1 of cement to 2 of sand, to brick was 38 lb. per square inch at an age of 7 days, and 59 lb. per square inch at an age of 30 days, while a cement of 1 part Portland and 1 sand, a year old, showed adhesive strengths varying from 29 lb. to 83 lb. per square inch according to the kind of brick used.

John Newman gives the tensile strength of a 6 to 1 Portland cement concrete as approximately 100 lb. per square inch.

This would show that good concrete possesses a tensile strength 25 per cent. greater than that of brickwork laid in

Portland cement, and although the recorded experiments are too few in number to give absolute certainty to any generalization made from them, still it seems safe to say that the difference is decidedly in favor of good concrete as against the best brickwork.

As regards resistance to crushing, General Gillmore found that brick piers 12 in. × 12 in., in section were stronger than cubes of concrete made from Rosendale cement, but weaker than cubes made from National Portland cement. Baker gives the ultimate strength of the best brick in Portland cement mortar as 180 tons per square foot, while cubes of concrete made of gravel and sufficient 1 to 2 Portland cement mortar to fill the interstices had a strength of 224.9 tons per square foot, and concrete made of 1 of Portland cement, 3 of sand and 6 of broken stone had a strength of 219 tons per square foot. So in this respect also concrete seems to be about 25 per cent. stronger than the best brickwork.

It must be borne in mind, however, that the strength given is for brickwork laid in Portland cement, which is rarely employed in ordinary brickwork, and that, therefore, concrete is really much stronger than such brickwork. Almost all writers on the subject speak of it in this way. Thus on page 115 of "Concrete, its Use in Building, etc.," Thomas Potter says: "Although 20 years ago Portland cement concrete was recognized as a material almost immeasurably stronger than ordinary brickwork, it is now, judging from recent tests, at the least calculation double that strength."

366. State some of the reasons for the increasing use of Portland cement concrete in the place of brick or stone masonry.

Ans. One of the principal reasons for the increased use of Portland cement concrete in the place of brick and stone masonry is found in the growth of knowledge as to the advantages and capabilities of concrete. When necessary it can be made to excel in strength and durability all other masonry except that made from the very best stone, while when great strength is not required it can be made less strong, with a reduction in cost that cannot be had under similar circumstances with brick or stone masonry. On foundation work it can be put in with a smaller expense for excavation and will give a more coherent, homogeneous structure, and one that is less subject to unequal settling, in case the soil is not uniform over its whole area, than will be the case with stone. It can be made water tight more easily than brick or stone. Under ordinary conditions as to the respective costs of the different kinds of materials it is cheaper than brick or stone masonry.

In addition to the recognition of its possession of the advantages named above another important reason for the increased use of concrete in large cities is that it can be made and put in place by unskilled labor, and work in which it is used instead of brick or stone is thus free from the vexatious and costly delays that are apt to be experienced with other masonry owing to the strikes declared for trivial causes by the masons' unions to which practically all the masons in such cities belong. This ability to use unskilled labor also frequently permits of the work being executed more rapidly on account of there being available more laborers than brick or stone masons. These considerations of freedom from union interference, and ability to secure unskilled labor more easily than skilled, have been very important ones in large cities during the past few years.

367. How would you determine the proper thickness of wall in designing a brick purifying house?

Ans. "The thickness of walls depends upon the weight they have to sustain and on their formation with proper materials so that their stability may be insured.

"A formula known as Rondelet's Rule is sometimes given, this is $T = \frac{LH}{N\sqrt{L^2 + H^2}}$ in which

H = Height of wall.

L = Length between cross walls.

T = Thickness of wall.

N = A constant, being 10 for brickwork, 12 for finely cut stone, 8 for imperfectly cut stone, and 6 for rubble.

"Thus to find the thickness of the wall of a building 60 ft.

long, 60 ft. wide and 30 ft. high we have by substituting, $T = \frac{30 \times 60}{10 \sqrt{3600 + 900}} = 2\frac{2}{3}$ ft. or 32 in. thick throughout its height and length.

"Berg, in his book 'Safe Building,' deduces a formula from Rankine's formula for long pillars, which is:

$$w = \frac{a\left(\frac{c}{f}\right)}{1 + \frac{l^2 n}{r^2}} \qquad (1)$$

Where w = Safe total load on the pillar.

a = Area of cross section in inches.

l = Length in inches.

r^2 = The square of the radius of gyration of the cross section.

$\frac{c}{f}$ = Safe resistance to crushing per square inch where c = total resistance to crushing and f = factor of safety of 10.

n = constant for brickwork 0.0033.

"Instead of using the height l in inches the formula may be modified to use it in feet. Substituting $12L$ for l, and the known value 0.0033 for n, we have

$$w = \frac{a\left(\frac{c}{f}\right)}{1 + \frac{144L^2 \times 0.0033}{r^2}} \text{ or } w = \frac{a\left(\frac{c}{f}\right)}{1 + 0.475\left(\frac{L^2}{r^2}\right)} \qquad (2)$$

Where w = Safe total load on piers, chimney or tower in pounds.

a = Area of cross section of pier in square inches at any point of height.

L = The height of wall in feet above said point of masonry.

$\frac{c}{f}$ = The safe resistance to crushing, per square inch.

r^2 = The square of radius of gyration of the cross section in inches.

"If it is more desirable to use feet and tons we take w =

2000 W, $a = 144$ A, and $r^2 = 144P^2$ and substituting we have

$$2000\,W = \frac{144A(\frac{c}{f})}{1 + 0.475(\frac{L^2}{144P^2})} \quad \text{or} \quad W = \frac{A(\frac{c}{f})}{14 + 0.046(\frac{L^2}{P^2})} \qquad (3)$$

Where W = Safe total load on masonry in tons of 2000 lb. each.

A = Area of cross section of masonry at any point of height in square feet.

L = Height in feet from said point to top of wall.

$\frac{c}{f}$ = Safe resistance to crushing in pounds per square inch.

P^2 = Square of radius of gyration, all dimensions taken in feet.

$\frac{c}{f} = \frac{1500}{10} = 150$ for good brickwork laid in lime mortar.

"When walls are long, without cross walls or buttresses, a piece of the wall is taken, one running foot in length, considering it to bulge inwardly or outwardly so that r^2 in formula (1) would equal $\frac{d^2}{12}$ where d = thickness of wall in inches. The area would then be, in square inches, $a = 12d$.

"Substituting these values in formula (2) we have

$$w = \frac{12d(\frac{c}{f})}{1 + 0.475\frac{L^2}{\frac{d^2}{12}}} \quad \text{or} \quad w = \frac{d(\frac{c}{f})}{0.0833 + 0.475\frac{L^2}{d^2}} \qquad (4)$$

If it is preferred to use tons and feet, insert in formula (3), A = D, where D = thickness of walls in feet, and also the value of P^2 = which is $\frac{D^2}{12}$ and we have

$$W = \frac{D(\frac{c}{f})}{14 + 0.046\frac{L^2}{\frac{D^2}{12}}} \quad \text{or} \quad W = \frac{D(\frac{c}{f})}{14 + 0.552\frac{L^2}{D^2}} \qquad (5)$$

Where W = Safe total load in tons of 2000 pounds on each running foot of wall D feet thick.

D = Thickness of wall in feet at any point of its height.

L = The height in feet from said point to top of wall.

$\frac{c}{f}$ = Safe resistance to crushing in pounds per square inch.

$f = 10$, c = Resistance to crushing of material used.

"Assuming a purifying house to be 60 feet long, 60 feet wide and 30 feet high, the distance between the beams supporting the purifying boxes and the roof to be 18 feet, and the distance from the beams downward to the foundation 12 feet; we first find the thickness of the wall above the beams and then the thickness of the wall below the level of the beams.

"In using formula (5) substitute for D different thicknesses until the safe thickness is found.

"Using the formula for determining the proper thickness of the wall for the above purifying house.

Formula:

$$W = \frac{D\left(\frac{c}{f}\right)}{14 + 0.552\frac{L^2}{D^2}}$$

assuming a thickness of 2 feet.

"The load per running foot above the beams supporting the boxes would be,

18 ft. (height) × 2 ft. (thick) × 112 lb. (weight of cu. ft. brickwork) = ...	4032 lb.
30 × 80 lb. (weight of roof including wind and snow) =	2400 lb.
18 ft. (height) × 30 lb. (wind pressure per sq. ft.) =	540 lb.
	6972 lb.

or 3½ tons.

"The safe load on a 24 in. wall 18 ft. high would be

$$W = \frac{2 \times 150}{14 + 0.552\frac{18 \times 18}{2 \times 2}} = 5.11 \text{ tons or } 10{,}220 \text{ lb.}$$

"The wall would be safe enough if ⅓ or ¼ of the wall were used up in openings.

"Assuming the wall to be 30 in. thick below the beams we have,

Load above beams per running foot,	6,972 lb.
Weight of wall, per running foot, 12 × 112 lb. × 2½	3,360 lb.
Weight of boxes and beams per running foot, 30 × 400 lb.	12,000 lb.
Wind pressure, per running foot, 12 × 30 lb.	360 lb.
	22,692 lb.

or 11½ tons.

"The safe load on a 30 in. wall 12 ft. high is

$$W = \frac{2.5 \times 150}{14 + 0.552\,\dfrac{12 \times 12}{2.5 \times 2.5}} = \frac{375}{26.718} = 14 \text{ tons, which would allow}$$

⅓ or ¼ for openings."

Berg states that these formulas give results that are apt to be in excess of the necessary strength, but that he prefers to have the fault on the safe side.

In actual practice purifying house walls would be built with pilasters instead of being of uniform thickness, as taken in the above method of arriving at the thickness. In this case the thickness of walls will depend upon the conditions of load. If the weight of boxes and floor is carried upon columns, then a 12-inch wall with pilasters, which is the thinnest wall that should be built, is heavy enough. In the usual purifying house construction the ends of the I beams supporting the boxes are built in the wall, and a stone bearing block, not less than 18 in. long and 10 in. wide, built in the wall for the beam to rest on. Knowing the load on this beam, the wall should be so proportioned that it does not have to sustain a load of more than 6 tons per square foot. Above the tops of the boxes the walls should never exceed 12 in. in thickness, unless the city building regulations require a thicker wall. The pilasters must be properly designed to carry the weight of the roof, and resist the overturning tendency of the wind.

SECTION VIII.—MISCELLANEOUS.

368. How should persons overcome by gas be treated?

Ans. The following answer to this question has been taken by permission of the company from the book "First Aid for Persons Overcome by Gas," issued by The United Gas Improvement Company for the use of its subordinates.

"When persons are affected by illuminating gas, they are in one of three classes:

"CLASS I. Those slightly affected—headache, dizziness and nausea, but still entirely conscious.

"CLASS II. Those seriously affected, but still breathing.

"CLASS III. Those apparently dead—not breathing.

"To properly treat these three classes, it is advisable to have on hand in an Emergency Kit the following materials:

"(*a*) A bottle of Weiss beer;

"(*b*) A bottle of aromatic spirits of ammonia;

"(*c*) A bottle of ordinary ammonia, with sponge attachment;

"(*d*) A tin cup;

"(*e*) A pair of tongue-pliers;

"(*f*) A towel.

"(*g*) A small jaw block.

CLASS I.

"SYMPTOMS.—Those slightly affected, complaining of headache, dizziness, nausea or vomiting, and great drowsiness, with relaxation of muscles, hurried breathing and rapid heart action

"TREATMENT.—Take patient immediately into fresh air, loosen collar and open shirt, at the same time walking him around, as shown in Figure No. 1. Give *Weiss beer while walking, as shown in Figure No. 2, followed in five minutes by a half teaspoonful of aromatic spirits of ammonia in a third of a glass of water. This dose may be repeated every fifteen minutes for not more than four doses. Walk him around until he recovers; then watch him, as he may have a sinking spell, in which event the same treatment must be renewed.

---

* Since these instructions were first issued it has been found advisable to use effervescing Phosphate of Soda (in individual dose bottles) instead of Weiss beer. Hence, where the latter is referred to the former can be used to advantage.

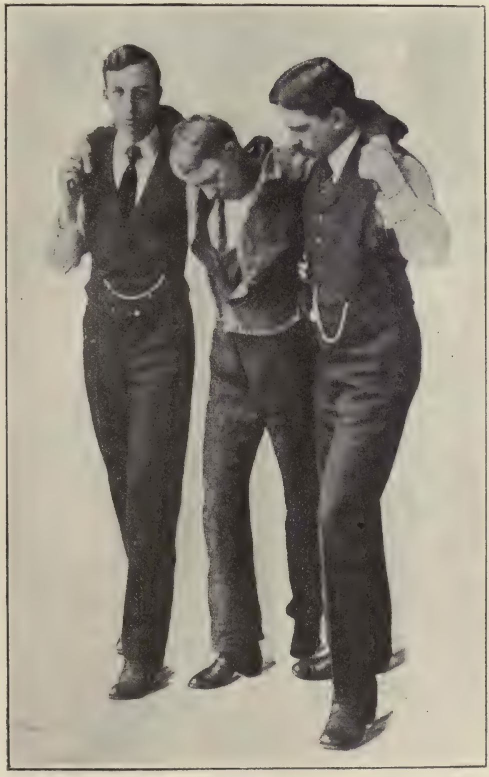


FIGURE NO. 1.

"Weiss beer is given to lift from the patient's stomach any gas he may have swallowed. However, if Weiss beer is not obtainable, plain soda-water will do. Aromatic spirits of ammonia is given as a stimulant for the heart and lungs, both of which are weakened by the effects of gas. In walking the patient, two men should support him, with one of his arms around the neck of each, as shown in Figure No. 1. If the patient is unable to assist in walking, or if at any time he ceases to walk, so that the toes of his shoes drag, as shown in Figure No. 3, it is a sign that he has entered the second class of cases. When this happens the walking should be stopped and the patient should be placed on his back and treated as explained in Class II.

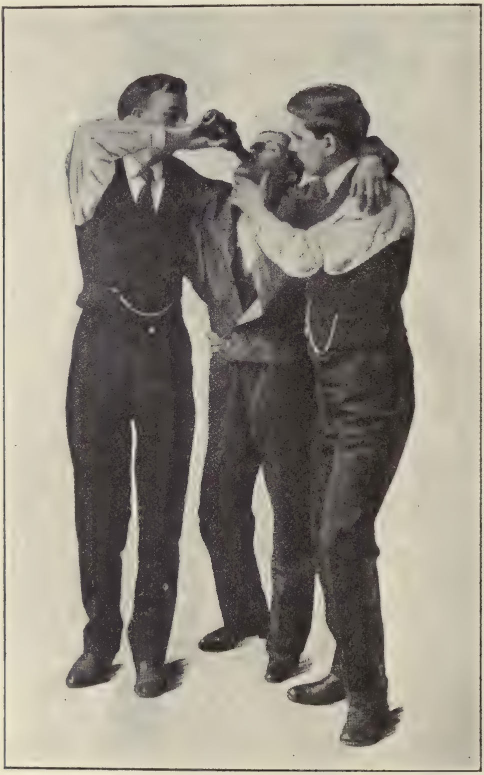


FIGURE NO. 2.

Class II.

"Symptoms.—Those seriously affected, but *still breathing*. The patient is apparently 'knocked out;' he is either half-conscious or unconscious—very weak, and his breathing is rapid and weak.

"TREATMENT.—*Send for a doctor at once.* Carry the patient immediately into fresh air. In this class of cases, he is too weak to walk, and is unable to swallow Weiss beer. Place him on his back on a flat surface, with a coat rolled (not folded) under the shoulders and neck, in such a way as to allow the head to fall backward enough to straighten the windpipe, as shown in Figure No. 4; at the same time open the shirt wide at neck and loosen the trousers and drawers at waist, and have two assistants rub his legs and arms hard. The sleeves and trouser-legs should be rolled up as far as possible so that the rubbing may be done on the bare skin, as shown in Figure No. 4.

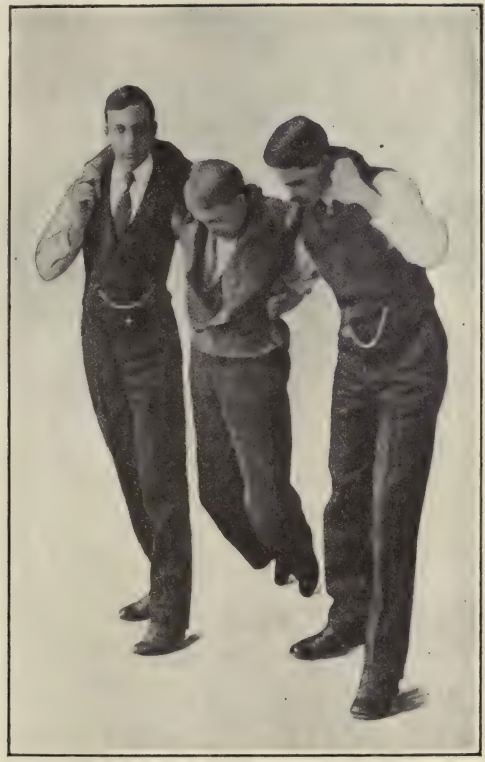


FIGURE NO. 3.

"If he is conscious enough to swallow, give him a half teaspoonful of aromatic spirits of ammonia in a third of a glass of water. This dose may be repeated every fifteen minutes for not more than four doses.

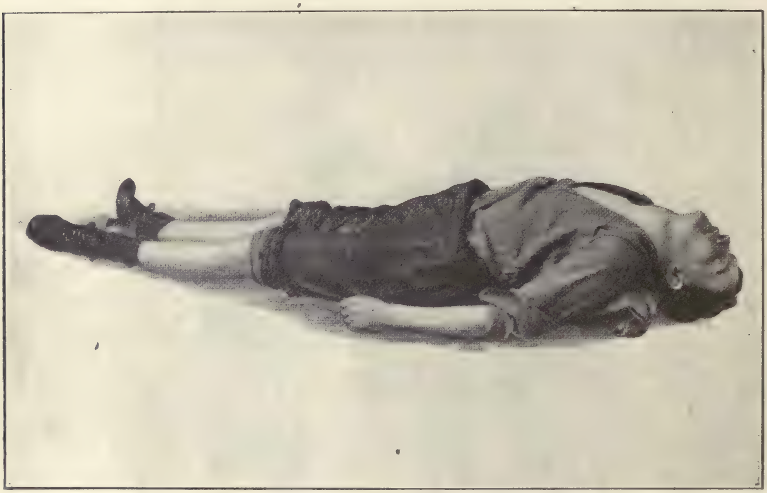


FIGURE NO. 4.

"If unconscious, open his mouth, forcing the jaw if necessary.

"(If the jaw is rigid, it can be forced open by placing the forefingers back of the bend of the lower jaw-bone and the thumbs of both hands on the chin, pulling forward with fingers and pressing jaw open with thumbs, as shown in Figure No. 5.)

"Place the jaw block, which should be large enough not to be accidentally swallowed, between the teeth to keep the jaws open and prevent the patient from biting his tongue, and grasp his tongue with the tongue-pliers, as shown in Figure No. 6.

"Clear froth from the mouth by putting in your forefinger as far as possible, and bringing up the froth with a scooping motion. Have the assistant who is holding the tongue slowly pass the bottle of ammonia with sponge attachment under the patient's nose about once a minute, as the patient breathes in, as shown in Figure No. 7.

Help the patient to breathe by pressing the *base of the ribs*

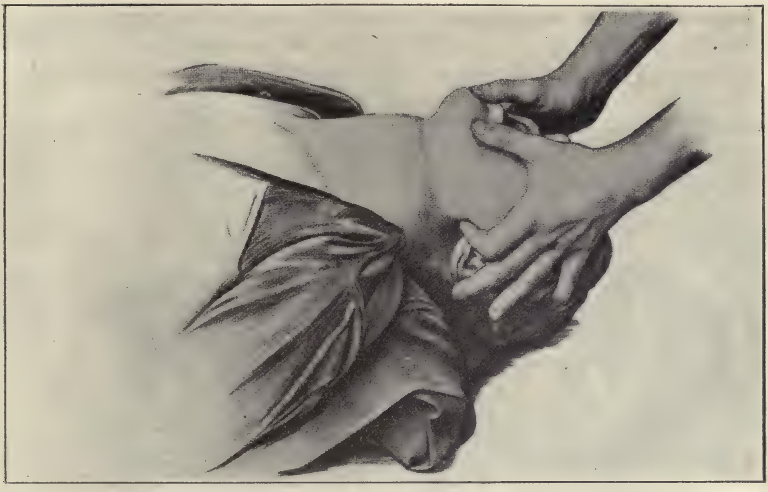


FIGURE NO. 5.

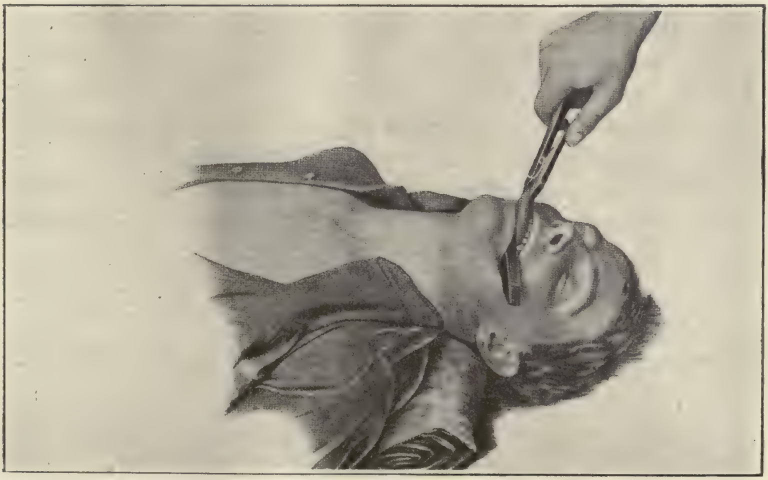


FIGURE NO. 6.

together *every other* time he breathes out, as shown in Figure No. 7. Do not press vertically, but press on the patient's side (palms of hands over lower ribs) in such a manner as to force as much air out of the lungs as possible. You can carry out this pressing action most successfully if, on beginning, you move your hands in and out with every breath, pressing very lightly, until you have established a rhythmical motion of your hands in unison with the patient's breathing; then you can begin to press hard at *every other* out-going breath.

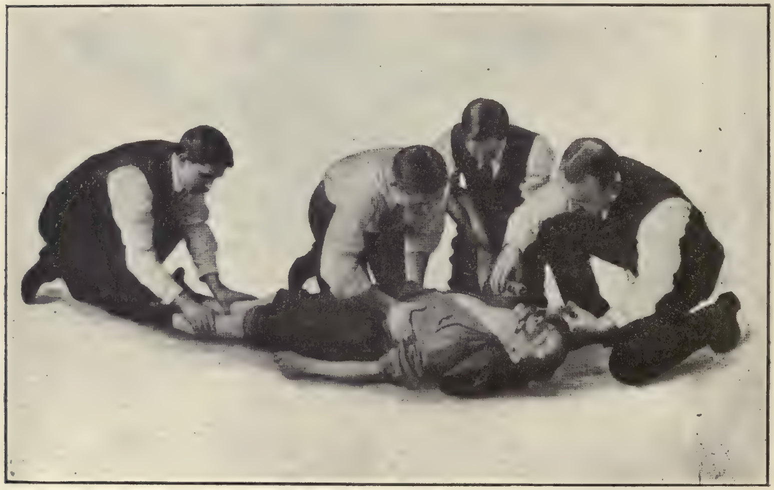


FIGURE NO. 7.

"(The object of doing this is to strengthen his breathing. By making the pressure *every other* time he breathes out, you give him an opportunity to take a breath himself, and this natural effort to breathe is in itself strengthening to the action of the lungs.)

"Continue this pressing action until the man is conscious and breathing well by himself.

"The rubbing of the arms and legs, as shown in Figure No. 7, the holding of the tongue, and the passing of the bottle of ammonia with the sponge attachment under the nose, should be continued as long as the pressing action is necessary. After he is conscious give him a half-teaspoonful of aromatic spirits of ammonia in a third of a glass of water. After you have brought him around, shift the coat or pillow from under his shoulders to under his head—see Figure No. 8—and surround him with bottles of hot water, as shown in Figure No. 8.

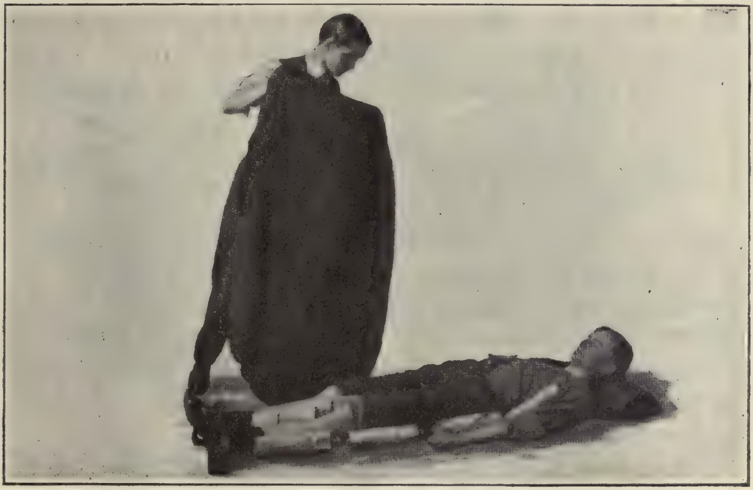


FIGURE NO. 8.

"(Beer bottles are easily obtained, and should be filled with hot water and covered with paper or cloth to prevent burning the flesh. Hot bricks also covered, or gas bags filled with hot water will answer as well.)

"Then cover him with a coat and watch him.

CLASS III.

"SYMPTOMS.—Those apparently dead—not breathing at all.

"TREATMENT.—*Send for a doctor at once*, in the meantime acting as follows: Carry the patient immediately into fresh air. Place him on his back on a flat surface, with a coat rolled (not folded) under the shoulders and neck, in such a way as to allow the head to fall backward enough to straighten the windpipe, as shown in Figure No. 4, at the same time open the shirt wide at neck and loosen the trousers and drawers at waist, and have an assistant rub his legs hard.

"(The sleeves and trouser-legs should be rolled up as far as possible, so the rubbing may be done on the bare skin, and the shirt and undershirt should be torn down the front so that they may be thrown back, leaving the chest and stomach bare, as shown in Figure No. 13.)

"Open his mouth, forcing the jaw if necessary in the manner previously explained.

"Place the jaw block, which should be large enough not to be accidentally swallowed, between the teeth to keep the jaws open and prevent the patient biting his tongue; grasp the tongue with the tongue-pliers, as shown in Figure No. 6, having an assistant hold it out while you are helping the patient to breathe, as described below.

"(In the absence of tongue-pliers, the tongue may be grasped between the index and second fingers, after they have been covered with a handkerchief.)

"Clear froth from the mouth by putting in your forefinger as far as possible and bringing up the froth with a scooping motion. Have the assistant who is holding the tongue slowly pass the bottle of ammonia with sponge attachment under the patient's nose about once a minute, when the patient is breathing in, and when his arms are being extended above his head, as shown in Figure No. 13.

"While you are preparing the patient as just described, an assistant should force the air out of the lungs by pressing the *base of the ribs* together about once every four seconds as described in Class II, and shown in Figure No. 7.

"After the clothing has been loosened, the jaw forced open, as shown in Figure No. 5, the froth cleared from the mouth and the tongue grasped, begin artificial breathing at once as follows:

ARTIFICIAL BREATHING.

"Kneel far enough behind the head of the patient to prevent interference with the man holding the tongue. Bend the patient's arms so that the hands meet on the chest; grasp the patient's forearms firmly, as close as possible to the bent elbows.

"I. Firmly press the patient's elbows against the sides of his body so as to drive the air and gas out of the lungs, as shown in Figure No. 9; then

"II. Raise the arms slowly with a sweeping motion until the patient's hands meet above (or behind) the patient's head, as shown in Figure No. 10; then

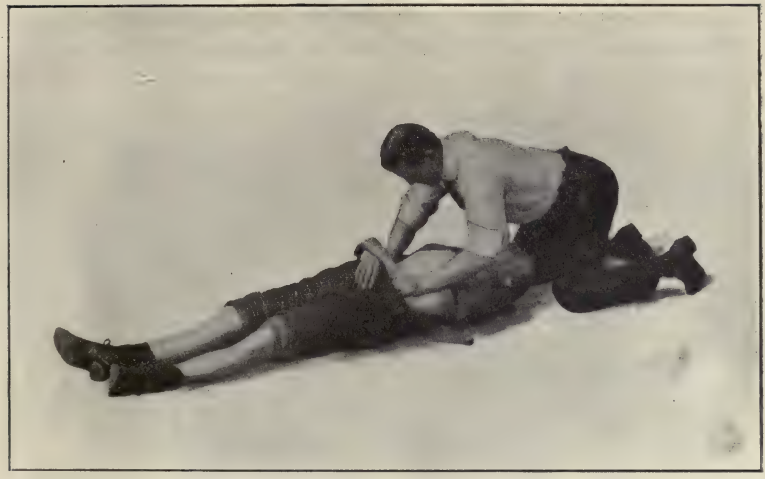


FIGURE NO. 9.

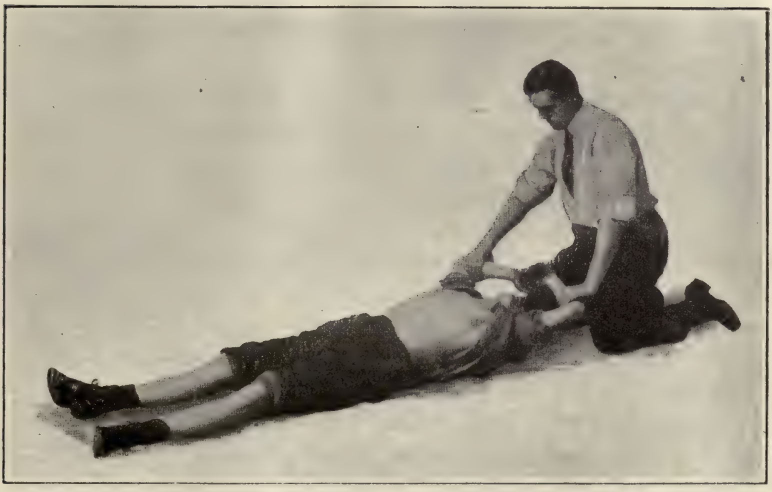


FIGURE NO. 10.

"III. While you have the patient's arms stretched out in line with his body, give them a slow strong pull until you have expanded or raised his chest as high as it will go, as shown in Figure No. 11; then

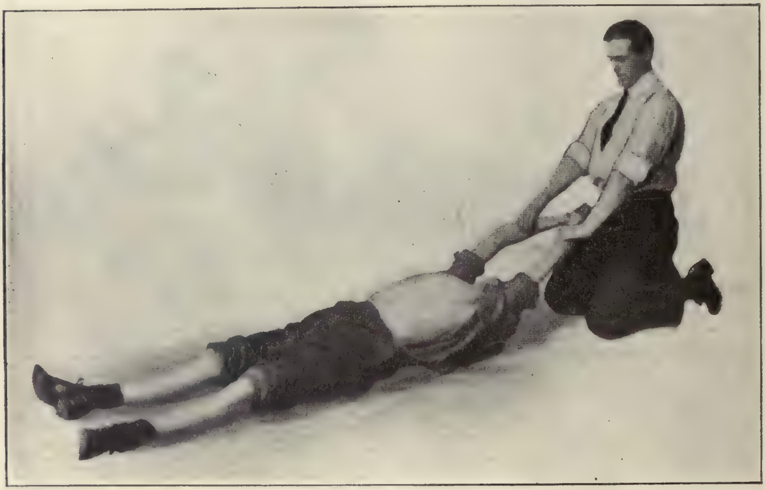


FIGURE NO. 11.

"IV. Bring the arms, with bent elbows, down against the sides, and firmly press them as before, as shown in Figure No. 9.

"This action should be continued about fifteen times a minute until the patient begins to breathe. You must guard against a tendency to make these motions too fast; they must be done slowly. A good plan is to count four slowly—'one,' as the pressure is given on the sides, as shown in Figure No. 9; 'two,' as the arms are being extended above the head, as shown in Figure No. 10; 'three,' as the strong pull is given, as shown in Figure No. 11; and 'four,' when the arms are again being bent and returned to the sides, as shown in Figure No. 12.

"Do not let your hands on the fore-arms slip away from the elbows; the best result comes from grasping close to the elbows, as shown in Figure No. 12.

"The operator must appreciate the fact that this manipulation must be executed with *methodical deliberation*, just as described, and never hurriedly or half-heartedly. *To grasp the arms and move them rapidly up and down like a pump-handle is both absurd and absolutely useless.*

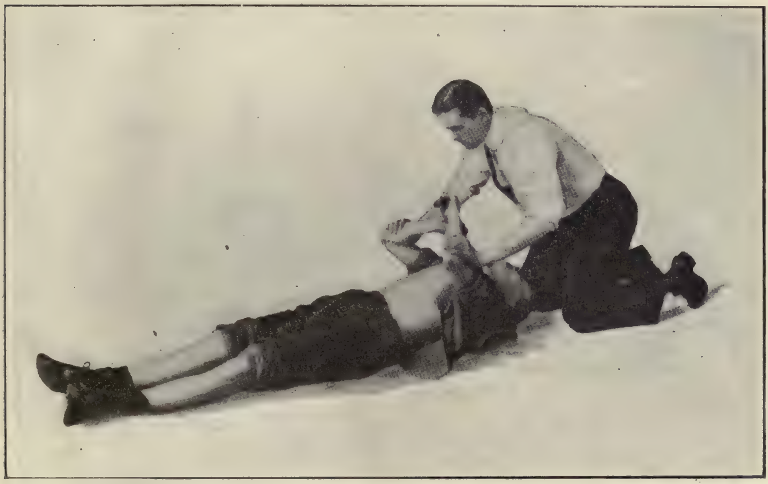


FIGURE NO. 12.

"Each time the arms are pulled above the head and the chest expanded, the assistant who is holding the tongue should pull the tongue out and downward, and another assistant should, from time to time, slap the chest with a towel or cloth wet with cold water, as shown in Figure No. 13.

"When the patient is breathing by himself, the process of artificial breathing can be stopped, but the process of pressing the sides *every other* time he breathes out, as described in Class II, and shown in Figure No. 7, should be again started and continued until he can breathe naturally (not too hurriedly) without assistance.

"The rubbing of the legs should continue as long as the artificial breathing, or pressing, is necessary, and the holding of the tongue, and the passing of the bottle of ammonia with sponge attachment under the nose as long as he is unconscious, as shown in Figure No. 7.

"After he becomes conscious, give him a half-teaspoonful of aromatic spirits of ammonia in a third of a glass of water. After you have brought him around, surround him with bottles of hot water.

"Then cover him with a coat and watch him.

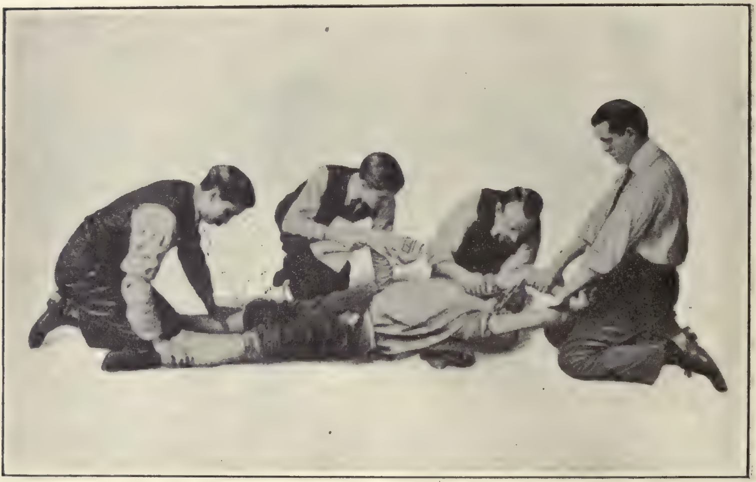


FIGURE NO. 13.

"In performing artificial breathing, if the patient does not show any signs of coming to life promptly, you should not be discouraged, but should continue the motions regularly for *at least one hour*, summoning such assistance as you may need. Cases are known where patients showing no signs of life after an hour's work have still recovered, and their recovery was due entirely to the faithful persistence of the person in charge.

"Persons who are affected by gas need *fresh* air; therefore, bystanders should not be permitted to crowd around the patient, and no one should be allowed to approach the patient except those carrying out these instructions.

"Should the articles contained in the Company's Emergency Kit for Asphyxiation Cases not be on hand when needed, a doctor should be sent for at once, and in the meantime every effort should be made to revive the patient, by following the course of movements described, until the doctor arrives and the necessary articles are secured."

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